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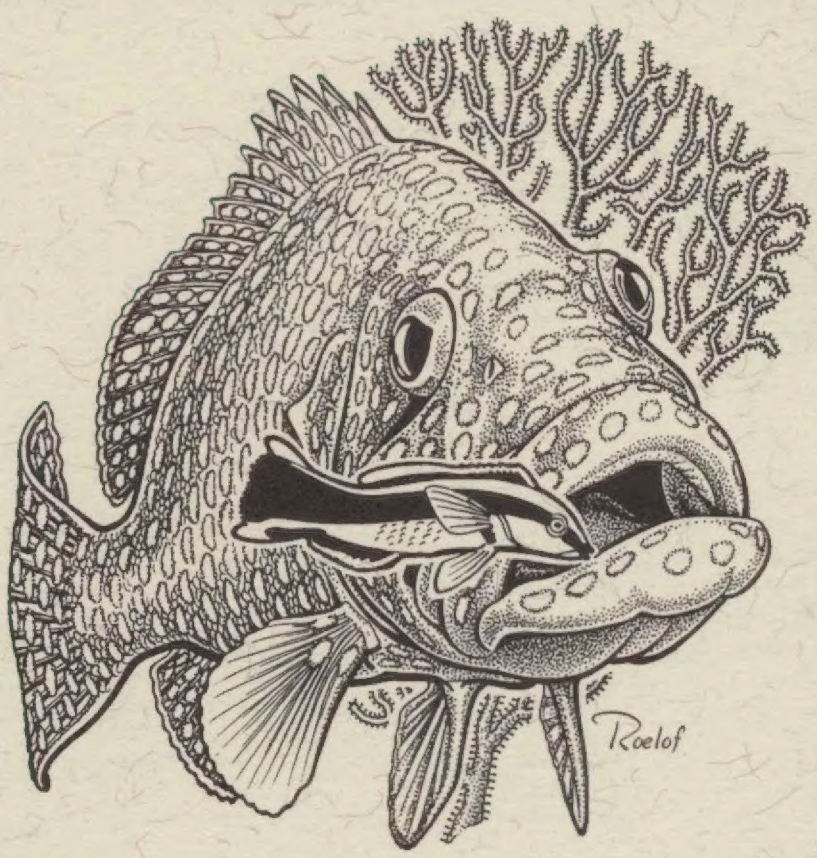

VOLUME 4 ■ NUMBER 3 ■ WINTER 1994

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Editor's Notebook

Aluminum Country Roads

My house is in the country. Each morning I walk or jog along a country road. It is a narrow, winding two-lane road with moderate traffic, woods, rock outcrops, and occasional fields. A walk through tall maple, birch, cedar, and pine woods puts one in contact and harmony with nature. It starts the day well. If you are lucky, you will see a cottontail rabbit hopping along, a fox snoozing, the flash of a bluejay, or hear a chickadee family calling to one another.

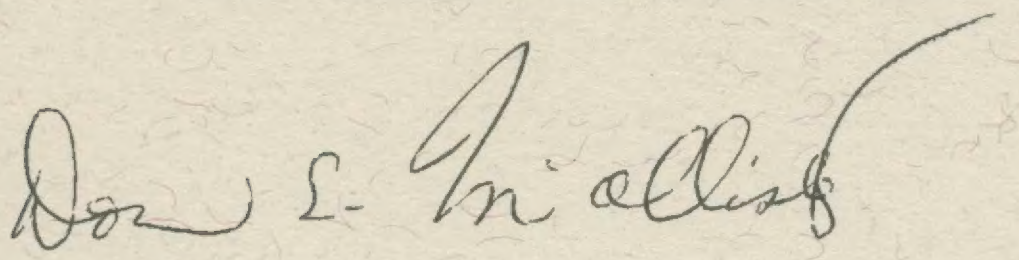
But too often you come upon cans and bottles thrown out of a car window. Last month, I did a count of this litter from a section a little less than a kilometre long. There were 10 aluminum cans, one steel can, two non-deposit glass or plastic bottles, and one returnable for deposit beer bottle. That makes 13 non-deposit containers to one returnable container—or 93%. The bulk of the non-returnables were aluminum cans—77%. These counts from my country road microcosm are not out of the ordinary for other roads and highways in North America.

What is there to be learned from this? Non-deposit approaches to recycling containers work far less well than the deposit approach. Aluminum cans are the chief offender. A deposit approach is needed to reduce environmental wastage. It will also create fairer market conditions among glass, aluminum, and plastic companies.

Aluminum requires enormous amounts of electric energy to produce. The raw material for aluminum, bauxite, is typically shipped long distances. The energy required to melt down recycled aluminum cans is higher than that needed to wash reuseable glass bottles. The throw-away non-deposit aluminum can culture thus consumes large amounts of electricity.

This style of aluminum can use therefore fosters large-scale hydroelectric development, the flooding of thousands of square kilometres of land behind dams, and modification of river, estuarine, and marine ecosystems downstream from the dams. This has a considerable impact on biodiversity. Aluminum containers discarded in garbages also have an environmental cost at city and country dump sites; those thrown out of cars affect the beauty of country roads and highways. Aluminum does have potentially positive environmental roles, for example, in small lightweight electric cars.

What did I do with the containers? I picked them up and took them to the recycling bins at the local dump. But that leaves a hundred kilometres of roads still littered in my township. Let's push for deposits on aluminum and plastic containers. Write your legislative representative today. Ask her or him to support thousands of like-minded citizens and to resisit lobbying by vested interests. Five minutes, a few pen strokes, paper, and a postage stamp can protect our landscapes and reduce power consumption by millions of kilowatts. Better still, pick up a well-flattened can from the roadside, paste a piece of card on it, write your message on it and mail it! Teach your children by example not to throw containers out the window; buy reuseable containers. Show your letter to your child before you send it.



Don E. McAllister

Editor

The goals of Global biodiversity are to:

- *Publish articles, views and news on biodiversity*
- *Bridge the gaps between professional disciplines & the public*
- *Communicate vital information to help humankind make decisions on the fate of the Earth's life*
- *Express views on the needs & value of biodiversity research*
- *Provide an international forum for discussing issues on biodiversity*
- *Enhance awareness of the role of biosystematic research & museum collections to conservation & ecologically sustainable use of biodiversity*
- *Discuss methods and philosophy of biodiversity conservation*
- *Review books and major articles on biodiversity*

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Cover image is a cleaner fish, *Labroides dimidiatus*, cleaning the mouth of a grouper (ocean bass), *Cephalopholis miniata*. This illustrates symbiosis, one of the functions of biodiversity.

Global biodiversity

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Global biodiversity is published quarterly. Annual subscription rates are $26.75 for individuals and $53.50 for institutions in Canada; $25 U.S. for individuals and $50 U.S. for institutions in United States and other developed countries; and $10 for individuals and $15 for institutions in developing countries.

Version française disponible:
La biodiversité mondiale
ISSN 1195-3101 (English edition)
ISSN 1195-311X (édition française)

Printed on recycled paper containing 10% post-consumer waste and using vegetable oil ink.

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A conceptual framework for the ecological functions of biodiversity

In the rush to put values on biological resources and biodiversity, ecological functions—what species and ecosystems do for other species and ecosystems—usually get left out. Nor are they yet included in national accounts kept by governments. Yet all are essential in sustaining biodiversity, the planet, and humankind. This landmark paper sets out a conceptual framework for examining these functions and deserves careful reading by all concerned with biodiversity, particularly those who manage and make decisions about biological resources and conservation of biodiversity. [D.E.M.]

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INTRODUCTION

This paper sets out the results of a study of an intriguing question: What are the specific ecological functions, which are carried out by natural ecosystems and/or their individual wild organisms, that have enabled the evolution of such an astounding variety of living things? Organisms and ecosystems are not only extremely diverse, pervasive, and persistent in themselves, but through their individual and collective functioning have participated in the creation of the ecosphere as a whole. What are the specific processes at work that are separate and in common and how can they best be classified?

Ecological functions are those processes that organisms and ecosystems perform or participate in. By doing so, they provide products for other species in their own community, and for ecosystems in nearby regions, or even in other parts of the world. The functions also profoundly affect the properties of soils, sediments, waters, and the atmosphere, which in turn determine the variety of living things. These natural processes have also enabled major new kinds of life forms to thrive, new functions to evolve, and more complex ecosystems to exist. Hence, this article does not ask the question: what do organisms and ecosystems do for people (i.e. what good are they?) but rather the more profound question: what have natural ecosystems and their wild organisms done to create the world within which we dwell?

Palaeontology has revealed that wild species and wilderness ecosystems have lasted for eons. Therefore, such systems represent the "norms" or normal environments of the ecosphere, and the organisms therein represent the varied end-products of evolution that took place within these emerging norms. By identifying and classifying these ecological processes we can better understand the creative, secure, and resilient path that the ecosphere has sustained for over three billion years.

Another motive behind preparing this framework was to provide some common ground for people who, like me, have been troubled for years by the vagueness of some important ecological terms: ecological processes, land health, ecological integrity, environmental quality, ecological complexes, and the like. The framework proposed here defines the individual ecological functions that comprise these larger notions and offers a logical arrangement for the functions.

Many of the functions described here have been widely identified and explored in the ecological literature (Leopold 1949; Daubenmire 1968; Lovelock 1988; Begon, Harper & Townsend 1990; Brusca & Brusca 1990; Schneider & Boston 1991; Wilson 1992; Norse 1993; Solbrig 1991, 1993; Grassle *et al.* 1992; Schultze & Mooney 1993), but these analyses lack a structured and unified system such as I propose. First, we need to examine the place of functions within the overall meaning of biodiversity.

THE FULL MEANING OF BIODIVERSITY

There are two complementary ways of thinking about and understanding biodiversity: the popular and the scientific. At the popular level, biodiversity is described as "the variety of life and its processes in an area" (Salwasser 1991). To this we can add that biodiversity recognizes "the ecological concept that everything is connected to everything else" (Council on Environmental Quality, 1993). The four key words in the popular definition are *variety, processes, connections*, and *area*.

The inclusion of "area" is essential because it provides a way of linking a theoretical discussion with what is actually happening to biodiversity on the ground. Only by looking at actual areas can we measure the success or failure of the management of biodiversity in those areas. We can measure the quality of the management through assessing the gain or loss of the functions described below. Unfortunately, the popular description does not describe these ecological functions and how they are related to the other four parts of biodiversity. For that we must go to the scientific definition.

Table 1 outlines the scientifically definable and inseparable parts of biodiversity: genetic, taxonomic, ecosystem, functions, and abiotic. Three of the five parts (genetic, taxonomic, and ecosystem) are widely recognized and reviewed in the literature, and so they will not be further reviewed in this article. But if the functional and abiotic components are excluded, a simplistic and misleading notion of both the meaning and importance of biodiversity is perpetuated. This paper details the functional component. The abiotic part is described by Rowe (1990a, 1990b, 1994) as the essential life-giving water/air/soil/sediment/mineral environment within which organisms and ecosystems evolved and are inextricably embedded.

BASIS FOR THE FRAMEWORK

Table 2 (page 5) identifies 21 ecological functions of biodiversity and organizes them into a logical framework of increasing complexity. The 21 components have been "stripped down" and exclude unnecessary detail. The functions are organized hierarchically into four groups starting with ones that are carried out mainly (but never entirely) by individuals and groups of individuals, moving to ones performed by small numbers of different species, and finally to ones that are the result of hundreds or thousands of different species working together at a community, regional, or landscape scale.

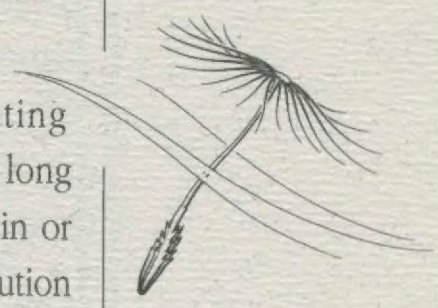
TABLE 1. THE FIVE PARTS OF BIODIVERSITY

(see also Mosquin, Whiting and McAllister 1995)

1. **GENETIC VARIATION** (genes in individuals of all living things)
2. **TAXONOMIC VARIATION** (species, genera, families, orders, classes, phyla, kingdoms, and other branches of the tree of life)
3. **ECOSYSTEM VARIATION** (the three-dimensional or cubic structures at the earth's surface (i.e. "habitats") and also, the large multi-cellular organisms themselves)
4. **FUNCTIONS, OR "ECOSERVICES"** (what organisms & ecosystems do for each other, their community, regional ecosystems, and for the ecosphere)
5. **THE "ABIOTIC" MATRIX** (the connected soil, sediment, water, air within which organisms and ecosystems have evolved)

The least complex of functions is primary production (function 1) since it mainly involves individual organisms operating without immediate assistance of other organisms—although with the help of energy from the sun (but necessarily within the inseparable abiotic component). Stability and harmony (functions 19 and 21) are at the most complex end of the scale because these are contingent upon the operations of many or most of the other functions. The functions contributing to biodiversity at the "ecosystem level" may include very different combinations of functions depending on the particular area or region one is examining or comparing. Generally, Table 2 reflects the observation and conclusion that mutual exclusivity of functions decreases as complexity of functions increases.

Functions are best appreciated by contemplating evolutionary processes that took place over very long spans of time. When an unique function originated in or among organisms of any taxonomic group, the evolution of a novel series of other things or functions (never present or possible prior to that time) was made possible. The framework portrays the incrementally increasing complexity of nature as new functions are made possible by the origination and establishment of prior functions.



Obviously, for areas heavily altered by human activities, the number of functions is greatly reduced or impaired while one or two may be vastly expanded. For example, primary production in a corn field is achieved at the expense of many former "wild" functions. As well, the variety and total number of functions vary greatly in different areas and climatic zones. Additional reconsideration of numbers of species involved in these functions as well as a further review of the biological and ecological literature could result in an improved classification, particularly as the activities of little known taxonomic groups of organisms are studied in soils, freshwater, and marine ecosystems.

Biodiversity functions are sometimes referred to as "ecoservices" (Ehrlich & Mooney 1983; Mosquin & Whiting 1992; McAllister 1992; Mosquin, Whiting & McAllister 1995). The term ecoservices should not be misunderstood. All organisms "service" themselves of course, and in so doing, they carry out functions that benefit or are required by other species or the community. For example, herbivores did not evolve only because of some anticipatory "intent" to provide a service to carnivores. Yet herbivory is a direct service to carnivory; once herbivory originated (independently in a great many different animal groups), other totally new species (carnivores) were able to evolve. The notion of ecoservices can be better understood by considering nutrient transport (function 6), trophic structure (function 16), decomposition (function 13), and some others. For instance, it is the piping of nutrients to plant roots by networks of fungal hyphae that is the ecoservice, not the plant conducting nutrients from its own root to its stem.

Biodiversity functions are polyphyletic, meaning that similar functions (e.g. nitrogen fixation, decomposition, carnivory, symbiosis, food webs, etc.) arose repeatedly in entirely different taxonomic groups and ecosystems. This suggests that there are consistent, normalizing internal dynamics to the emerging ecosphere as a whole. Or, in other words, innate "self-realizing" processes must make possible the emergence of parallel functions in different taxonomic groups and ecosystems around the world.

The later functions are usually dependent upon the earlier ones. Looked at from this perspective, the complexity of the developing ecosphere gradually increased over billions of years. This increasing scale of complexity through time could be considered the "law of biodiversity functions." A general rule might state: "All biodiversity functions, except primary production, are derived from and dependent upon pre-existing functions." In fact, it may be accurate to claim that it was the biodiversity functions that enabled the ecosphere to evolve, persist, and become ever more complex over several billion years, a topic now under active investigation (Schneider & Boston 1991).

In the following analysis of functions, reference is made to many taxonomic groups (which carry out these functions). A more exhaustive listing of these groups with comments on their ecological functions is provided in Mosquin, Whiting, and McAllister (1995).

ANALYSIS OF THE 21 BIODIVERSITY FUNCTIONS

A. FUNCTIONS PERFORMED PRIMARILY BY INDIVIDUALS

1. Primary Production

Primary production is the capture of energy from sunlight through photosynthesis and produces carbohydrates, fats, proteins, and other organic compounds needed by all herbivores for food. But it is not primary production in itself that is responsible for the megadiversity of dependent herbivores, carnivores, and detritivores in all major ecosystems. Rather, it is the sheer variety of organisms engaged in the primary production function, the stupendous variety of carbohydrates, proteins, and fats produced, and the great diversity in the actual form in which biomass is produced. Thus, some primary producers are photosynthetic bacteria that feed protozoans, which feed microinvertebrates, which feed larger invertebrates and vertebrates as in aquatic ecosystems. Other primary producers, such as trees, shrubs, and herbs, are so large and diverse that they create habitat (both within themselves and as 3-D ecosystems—function 17) for all manner of life. It is also interesting to note that primary production is sometimes

The Sunflower, *Helianthus annuus*, illustrates primary production, the capture of energy from sunlight through photosynthesis.

TABLE 2. A FRAMEWORK FOR THE ECOLOGICAL FUNCTIONS OF BIODIVERSITY

A. FUNCTIONS PERFORMED PRIMARILY BY INDIVIDUAL ORGANISMS

1. Primary production (creation of biomass or volume of living matter by photosynthesis)
2. Oxygen production (oxygen producing plants, animals, and micro-organisms)
3. Herbivory (protozoa, fungi, and animals eating primary producers)
4. Carnivory (protozoa, fungi, and animals eating protozoa and animals)
5. Population moderation—a specialized aspect of herbivory & carnivory—(diseases, parasitism upon over-abundant species, and "overgrazing" that creates new niches for other species.)(This function could be placed in group B or even C below.)
6. Nutrient transport (by individual organisms)
7. Sequestering of carbon dioxide

B. FUNCTIONS INVOLVING INTERACTIONS AMONG LOW NUMBERS OF DIFFERENT KINDS OF ORGANISMS (These functions are carried out because of the co-existence of usually unrelated species in an area, often in immediate proximity, or from time to time.)

8. Seed & spore dispersal (plants); migration (animals)
9. Control of soil erosion
10. Symbiosis (mutually beneficial, intimate, co-evolved associations, which are extremely widespread and variable in nature). Some examples include:
    a. nitrogen fixation (especially by bacteria and algae in higher organisms; lichen partnerships)
    b. flower pollination involving insects, birds, etc.
    c. mycorrhiza involving fungi and plant roots
    d. food digestion involving bacteria and fungi in the gut of animals
    e. "fish cleaners" on coral reefs

C. FUNCTIONS INVOLVING COMPLEX INTERACTIONS AMONG LARGE NUMBERS OF DIFFERENT ORGANISMS (These functions represent an increased level of complexity and some might better be included in "D" below.)

11. Soil creation and sediment bioturbation
12. Moderation of macro & microclimate
13. Decomposition (primary & secondary detritivory; including digestion, mineralization of organic compounds, fermentation, etc.)
14. Maintenance of 3-dimensional, structures–consequences of multicellularity (trees, shrubs, herbs, kelp, larger animals, forests, soils; creation of "habitat")
15. Communication–both intra- and inter-specific (sight, sound, taste, smell, touch via colour, shapes, pheromones, camouflage, bioluminescence, radar, etc.)

D. ECOSYSTEM FUNCTIONS & PROCESSES (dependent upon many or most of the above contributory functions of organisms)

16. Food webs (trophic structure)
17. Biogeochemical nutrient cycling (ecosystem and ecospheric scale).
18. Maintenance of genetic diversity.
19. Stability (consequences of disturbances, keystone species, foraging behaviour, species richness, similarity of function, "redundancy" of function, etc.)
20. Community succession (with or without disturbances)
21. Harmony (a combination of form, movement, structure, and functions resulting in a proportionate, orderly, and integral whole)

greatly increased through symbiotic associations among organisms (function 10) (Hawksworth 1992).

2. Oxygen Production

The production of "free" oxygen through photosynthesis by primary producers is a function that has two entirely different beneficial results. First, it provides the oxygen necessary for all oxygen-requiring biota and the operations of most decomposition (function 13). Second, this organically produced oxygen is the source of Earth's protective ozone shield (Schneider & Boston 1991).

Primary producers that create biomass and oxygen
▪cyanobacteria ▪chloroxobacteria ▪all algal phyla ▪lichens ▪mosses ▪all (except saprophytic) vascular plants

3. Herbivory

The digestive system of a primary herbivore, the black-mound termite king, *Amitermes attanticus*. The bulky intestine has 3 pouches filled with semi-liquid, dark-coloured food in which can be seen 6 relatively large, free-swimming protozoan symbionts of the species *Nyctotherus silvestrianus*.

Herbivory is the function of protozoans and animals eating primary producers. The repeated emergence of this function early in Earth's history has created the diverse world of herbivores in all ecosystems. While herbivory is a characteristic function of plant-eating vertebrates and invertebrates, remember that there are very large and diverse taxonomic groups in aquatic ecosystems that acquire their food by filtering the water in which they live. As a consequence, their evolution has been shaped by both herbivory and carnivory.

Herbivores
▪protozoans ▪rotifers ▪many molluscs ▪many crustaceans ▪nematodes ▪millepedes ▪most insects ▪symphylids ▪springtails ▪waterbears ▪kinorhynchs ▪many echinoderms ▪many fishes ▪immature amphibians (tadpoles, salamanders) ▪some reptiles ▪many birds ▪many mammals

4. Carnivory

Carnivory is the eating of herbivores and other carnivores. Without the innate potential for carnivory, the vast array of carnivores would not have evolved and complex trophic structures (function 16) would have been far simpler. Also, the harmony found in nature (function 21) has been greatly increased by the presence of carnivores.

Both herbivory and carnivory constitute a kind of "superfunction" where organisms eat other organisms. The act of predation is not considered to be a function but only part of the mechanism through which the carnivory function is performed. Herbivory and carnivory are inextricably linked to decomposition (function 13), since food needs to be digested to provide the energy for living.

Carnivores
▪protozoans ▪sponges ▪hydroids ▪combjellies ▪various worm groups ▪molluscs ▪many crustaceans ▪spiders ▪many insects ▪all centipedes ▪all lampreys ▪sharks ▪most bony fishes ▪amphibians (adults with one exception) ▪most reptiles ▪many birds ▪many mammals ▪a few vascular plants

5. Population Moderation

Population moderation refers to the ways in which diseases, parasites, herbivory, or carnivory naturally limit runaway population increases or "blooms" of individual species. The phrase "balance of nature" is a popular observation on the consequences of population moderation. The cyclical dynamics of predator/prey relationships and herbivore/plant relations provide examples of this function. Microparasites and macroparasites often are major factors in controlling population. Humans are unique because we have controlled many of our parasites and predators so the feed-back mechanisms naturally limiting our populations have largely ceased to operate in the normal manner. Hence, at least in the short term, humans have escaped from the norms of the ecosphere.

Population Moderators
▪viruses ▪many phyla of bacteria ▪fungi ▪protozoa ▪many invertebrates ▪many herbivores ▪many carnivores

6. Nutrient Transport (by individual organisms)

This function is the physical transport of nutrients (phosphorus, potassium, nitrogen, and trace elements) via living tissue to new places in the ecosystem. For instance, fungi carry nutrients through hyphae in soils, the leaves of plants blow from one place to another, and all mobile animals carry nutrients to new places in their droppings and eventually upon their death.

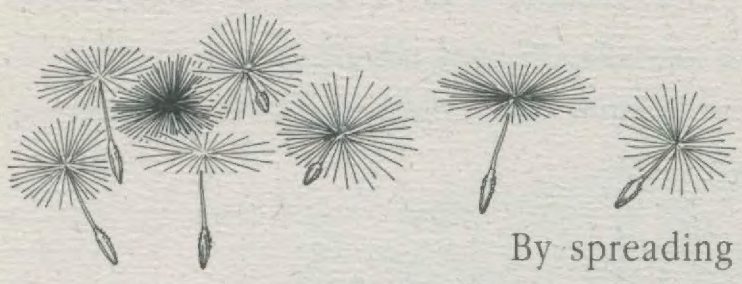
7. Sequestering of Carbon Dioxide

This is the active contribution made by diverse life forms as they remove carbon dioxide (CO_2) from the atmosphere, soils, and waters by precipitating calcium salts, amassing organic deposits, or incorporating CO_2 into living biomass. While stress here is placed on CO_2, living things also remove other compounds, particularly toxic substances from ecosystems, and add them to accumulating muds or sediments. This latter process is not insignificant. Because of this function, we find such things as deposits of marine chalk, limestone, and peat plus coral reefs and the biomass tied up in trees, shrubs, and herbs.

Carbon dioxide removers
▪Marine cyanobacteria ▪algal protoctists ▪protozoan protoctists ▪hydroids ▪mosses ▪forbs ▪woody plants ▪trees ▪shrubs ▪herbs

B. FUNCTIONS INVOLVING INTERACTIONS AMONG LOW NUMBERS OF DIFFERENT KINDS OF ORGANISMS

8. Seed and Spore Dispersal; Animal Migration



By spreading seeds, spores, or reproductive animals to new areas or regions, individual species can reach the optimum range within which they can test their genetic system for survival and adaptation. Dispersal, in one form or another, is a characteristic function of all organisms and facilitates the emergence of new adaptive variants throughout the range of a species and beyond. This function is critical to re-colonization and restoration of natural ecosystems in places where they have been injured, destroyed, or highly modified, and where new conservation objectives are the goal. As well, the successful long-distance dispersal or migration of organisms has been a key function essential to the evolution of the world's unique endemics on remote oceanic islands or in near identical terrestrial ecosystems in different parts of the world.

9. Control of Soil Erosion

The control of soil erosion by vascular plants, especially in terrestrial ecosystems, is a particularly powerful function. It is characterized by extensive root growth and development, accumulation of an organic soil layer, litter accumulation, and thus, major nutrient retention and recycling. In such circumstances, soil builds up faster than wind and/or water can carry it away. The consequence is the literal transformation of the biodiversity of plants, animals, and associated microorganisms in an area.

As well, aquatic vascular plants and some algal phyla play an important role in estuaries and in freshwater sites in reducing erosion. In shoreline marine areas, kelp beds and eel grass beds play a similar role in reducing the loss of enriched sediment.

10. Symbiosis

Symbiosis is the mutually beneficial, intimate, co-evolved association of a species with another (usually unrelated) species where both organisms benefit. The degree of interdependency between symbionts varies greatly. Symbiosis is one of the most powerful functions of biodiversity. As unrelated organisms began to depend on each other, new kinds of life forms originated. There are tens of thousands of co-evolved symbiotic systems operating between and among species in all ecosystems in virtually all phyla of living things (Parker 1982; Margulis & Schwartz 1988; Brusca & Brusca 1990; Begon *et al.* 1990). In the dawn of life, symbiosis brought many submicroscopic organisms together permanently and shaped the world of life as we know it today. Thus, all individual cells of "eucaryotes," or those species that have discrete nuclei in every cell, are now known to be permanent successful symbiotic systems indicating that ecological functions operate even at the cellular level. We cannot know the potential consequences of today's symbiotic systems, but obviously the loss of any species, however small, may substantially decrease the life forms of tomorrow.

Some Forms of Symbiosis

▪Mycorrhizal associations between fungal hyphae and plant roots, where fungi make possible the more efficient mineral absorption by root hairs of vascular plants and the fungi obtain essential sugars in return

▪Lichens involving a green algae and/or a nitrogen-fixing cyanobacteria with a fungal partner, where nutrients are provided to the fungal host while living space is provided for the algae and/or cyanobacteria

▪Pollination, where an enormous variety of insects, birds, and bats have evolved to pollinate flowering plants, and where in turn, flowering plants have developed an enormous diversity of flower sizes, colours, and shapes in direct response to the various activities of their pollinators.

▪Bioluminescence, where a cool chemical light is provided by a bacteria for its host in return for shelter and nurture.

This picture of the bigeye flashlightfish, *Protomyctophum thompsoni*, illustrates bioluminescence—one of the forms of symbiosis—in action.

C. FUNCTIONS INVOLVING COMPLEX INTERACTIONS AMONG LARGE NUMBERS OF DIFFERENT ORGANISMS

11. Soil Creation and Sediment Bioturbation

The growth of roots and fungal hyphae and the tunnelling by worms and other soil invertebrates builds, aerates, and maintains soils (Brady 1984). In terrestrial ecosystems, the control of soil erosion by plants (function 9) enables this function to become fully developed. Soils are unique living ecosystems created and maintained by a great variety of living organisms, present by the tens of thousands in each cubic centimetre of soil and sediment. Countless biochemical processes take place in these ecosystems including different types of decomposition, recycling of carbon, nutrients, and others. In marine sediments, many species live in the sediment and bring about a constant mixing of sediment from deeper layers.

Soil Creators and Sediment Mixers

On Land

▪bacteria ▪cyanobacteria ▪algae ▪fungi ▪arachnids ▪many orders of insects ▪plants (roots, leaves, dead trunks)

In Oceans

▪all bottom dwelling groups that burrow in sediment, bore holes in rocks, or chew up coral to make sand.

Worms and other soil invertebrates help build, aerate, and maintain soils.

12. Moderation of Macro and Microclimate

Macroclimate is the single most dominant abiotic influence upon the biodiversity that can develop in any region. It includes the prevailing weather conditions of an area as described by temperature and other meteorological conditions over a period of years. The distribution of major ecosystems such as tundra, boreal forest, desert, or rain forest is determined by macroclimate. However, once firmly established, vegetation significantly affects these ecosystems both locally and in distant areas in two ways. First, the kind of vegetation (or lack of it) influences the percentage of sunlight reflected from an area, and this influences temperature. Second, transpiration from forest canopies and ground vegetation can increase relative humidity in the atmosphere, which in turn affects rainfall and determines the biodiversity present in an area. Air temperature and rainfall in more distant regions can also be affected.

The effect of plants upon the microclimate is profound in both terrestrial and aquatic ecosystems. Through shading and humidity, trees, shrubs, forbs, grasses, and mosses have major moderating influences upon the microflora and fauna of an area. In contrast, the fauna and flora in areas devoid of plant cover (such as deserts or cultivated fields) are greatly affected by the extremes of light intensity, humidity, temperature, and wind.

13. Decomposition

Decomposition or detritivory is the natural recycling of the residues of life. This process takes place universally in all ecosystems and also within many larger organisms themselves (i.e. decay, digestion, etc.). Next to primary production, decomposition is the most important of functions, and a wide range of life forms from bacteria to humans clearly determine and control the detritivory function. Most decomposers require oxygen (function 2), and their activities can be classed as either primary or secondary detritivory.

Primary detritivory is the absorption of free organic molecules as food. Bacteria obtain all their food in this way, as do two phyla of marine worms. Bacteria metabolize these molecules to create nutritive blocks (called plaques) that are then eaten by multitudes of protozoa and other plankton (functions 2 and 3). Together with photosynthesizing algae and cyanobacteria (function 1), these plaques are the primary "pastures" for all freshwater and marine food chains (function 16). Fermentation is a specialized form of primary detritivory.

Many phyla of bacteria (Margulis & Schwartz 1988) have developed this powerful ecological function: they ingest toxic molecules produced by industry and reduce a portion of them to less harmful substances and minerals. These mineralizing bacteria can be amazingly abundant in many ecosystems, and therefore, play an influential role in returning soils and waters to a more normal or pristine condition.

Secondary detritivory is the "digesting" of dead animal and plant tissue and its degradation into simpler organic compounds. Both non-filter feeders and filter feeders are secondary detritivores because they cannot discriminate between living organisms and floating dead biomass. Without the services of primary and secondary detritivores, there would be no way of cleansing the ecosphere of the "products" of life. Indeed the great oil deposits of the Earth may have been created only because the decomposition function had not yet been as perfected as it is today.

14. Creation and Maintenance of 3-D Ecosystem Structures

The repeated capability of different phyla to evolve multicellular structures and the consequences to habitat formation is the basis for this function. During the long history of life on Earth, small and large multicellular organisms have profoundly affected associated organisms and made possible the obvious 3-D spatial structure of ecosystems such as forests, tundra, prairie, kelp beds,

submergent freshwater plant beds, coral reefs, and others. As well, most larger organisms provide homes for various biota, such as wood-boring insects, cavity-nesting birds, fish seeking the protection of coral reef structures, and so on. As a consequence of multicellularity, entire assemblages of new life forms have evolved to live in and depend on these structures and systems. The 3-D structures can be submicroscopic in the sense that even single-celled organisms often have parasites or parasitic symbionts living within them.

Creators and Maintainers of 3-D Ecosystems

Marine

▪tall sponges ▪macro algae (green, red and brown) ▪large sea animals

Terrestrial

▪herbs ▪shrubs ▪trees ▪large land animals

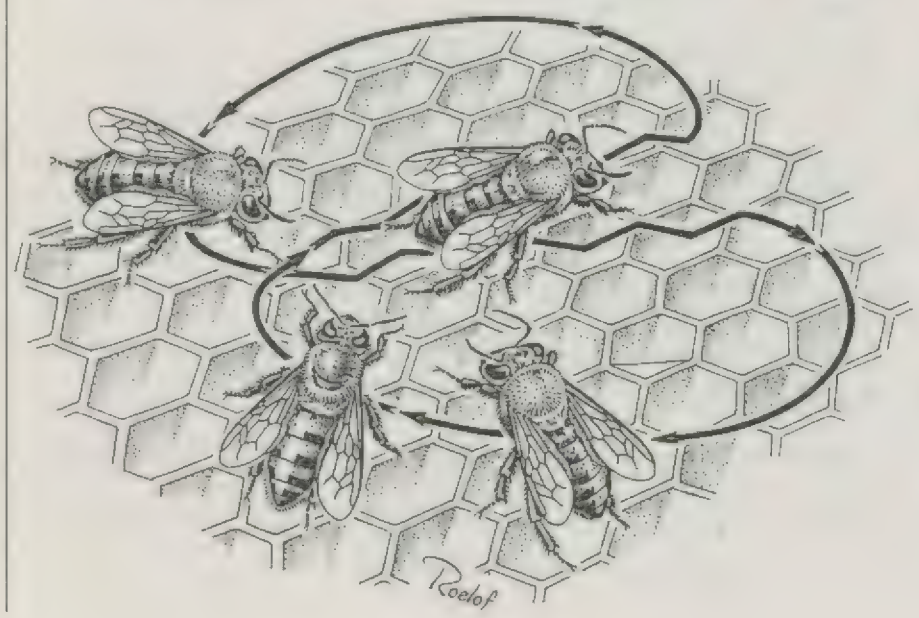
Freshwater

▪all submergent vegetation ▪larger animals

15. Communication

Communication is an ecological function because it has a tremendous effect upon the substance, nature, and quality of species and ecosystems. This is a major, widespread, and essential function of all complex life forms. A diverse array of methods and variations of contact between individuals of the same species and between different species have evolved and co-evolved and are now part of the natural taken-for-granted processes in ecosystems.

Methods of communication vary from simple chemical sensory abilities in more primitive mobile organisms to the use of taste, sight, touch, sound, radar, sonar, the sending and detection of electric currents, and other specialized methods in higher life forms. Communication between organisms, and between organisms and their surrounds, influences all manner of activity: courtship, parenting, food gathering, migration, herding, flocking, and escape from carnivores. In particular, the evolution of sight has had a stupendous impact upon the evolution and origination of colour in many species and ecosystems. Likewise, the use of sound in communication has produced what can only be described as a truly wondrous diversity of animal sound and song, some of which humans can only discover through the use of special scientific instruments. In the sense that communication is the very product of the evolution of biodiversity, much that is beautiful and meaningful to people in this world will certainly vanish as biodiversity is reduced.



The figure-eight "waggle dance" of the honey bee, *Apis mellifera*, is performed by a worker to communicate to recruits the distance and direction of a food source.

D. ECOSYSTEM FUNCTIONS AND PROCESSES

16. Food webs (trophic structure)

The pattern of movement of energy through organisms in communities defines the food webs or the trophic structure that exists therein. Food webs are considered as a separate ecological function because of the consequences to species and ecosystems. All food chains and webs begin with primary production (function 1). Most bacteria, all fungi, protozoans, animals, and a few plants cannot manufacture their own food and hence are always at higher (dependent) trophic levels. A detailed discussion of trophic structures is presented in Begon *et al.* (1990; 798-815).

Food webs range from simple to complex. A simple web or chain would be where primary producers are eaten by herbivores, which are then eaten by other vertebrate carnivores. In this case, the evidence of discrete levels is obvious. However, the trophic structure among microorganisms and invertebrates is complex because many invertebrates are filter feeders, and most zooplankton will ingest any bit of organic material whether it be phytoplankton, bacteria, other zooplankton, or detritus. Another example of complexity lies in the trophic levels and relationships among soil biota and sediments. These are poorly understood—most of their species have not even been described by science (Mosquin and Whiting 1992; Mosquin, Whiting and McAllister 1995). But hypothetically, energy must move through many interlocking levels involving different kinds of cycles and cycles within cycles.

17. Biogeochemical Nutrient Cycling (ecosystem & ecospheric scale)

Nutrient cycling is not only a local function (function 6), but is also global in nature, and its presence is an explicit example of the fifth or abiotic part of biodiversity. Pervasive and complex, these "ecospheric" nutrient cycles have profound effects upon the distribution and occurrence of ecosystems and the

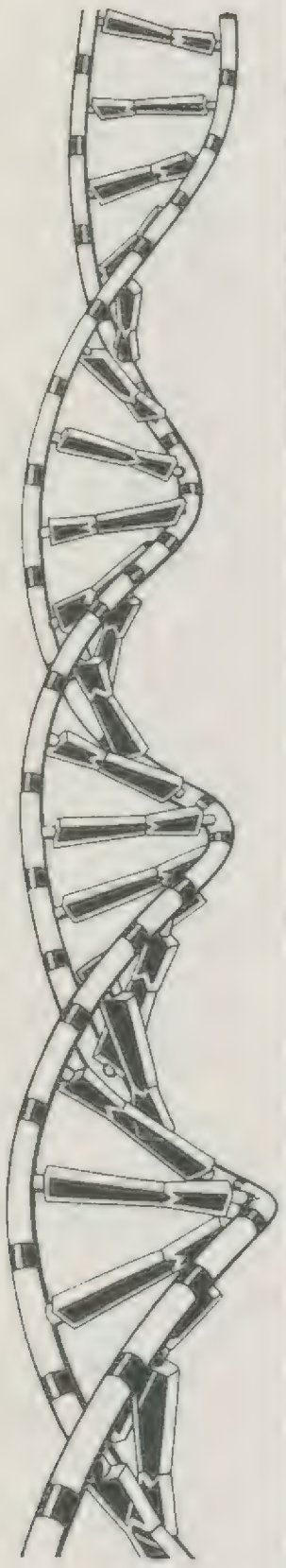
abundance of many species. All major elements required by plants and animals move in cycles both within the biosphere and in the abiotic matrix of the ecosphere. Nutrients are recycled and reused again and again; the term "biogeochemical" cycles has been coined to emphasize the essential part that organisms play in this process. Some measure of the scale and evolutionary consequences of this function can be gained from the example of calcium. All calcium carbonate of the great limestone deposits of the earth was precipitated by living organisms in marine systems from dissolved CO_2. This is almost the exclusive source of the calcium in bones of vertebrates and exoskeletons and shells of invertebrates.

Human activities (through agriculture, industry, municipalities) contribute abnormal amounts of nutrients into waters, soils, and the atmosphere. These nutrients often accumulate to the extent that the functioning and kinds of natural ecosystems in freshwater and marine shoreline areas are drastically affected. Excessive nutrients can have much to do with the destruction of coral reefs (McAllister 1994). Such "eutrophication" affecting lands and freshwaters in many areas, and major substitutions of species are resulting. Also, the functions of species and ecosystems of affected areas and regions are often drastically altered.

18. Maintenance of Genetic Diversity

Depending on species and community, an enormous panoply of mediating agents, both biotic and abiotic, are involved in transferring genetic material leading to reproduction. Altering these mediating agents profoundly affects the presence, abundance, and distribution of species and ecosystems.

While mechanisms of reproduction in individual species are largely internal or co-evolved, they range from ones that clearly maintain or promote genetic variability to ones that limit genetic diversity through the presence of very conservative genetic systems. The specific mechanism that maintains genetic variability varies greatly among phyla. In animals, bisexuality is the norm, so that two sexes are present in almost all species. "Asexual" reproduction or hermaphroditism plays a role in some species. In contrast the mechanisms in higher plants are diverse (See Mosquin 1966 for more detail). All these forms of reproduction (except strict self-pollination) are "mediated" by the matrix in which individuals of a species find themselves.



A number of biotic and abiotic factors influence the transference of genetic material.

Among many animal species, genetic variation of a remnant population (and hence its reproductive viability) cannot be maintained once the number of breeding pairs have been drastically reduced. Many cases are known worldwide where animal populations have been reduced to such low levels that reproduction among the surviving individuals is very low with extinction always a possibility due to inbreeding depression .

19. Stability

The geological and historical basis for recognizing stability as an ecosystem function stems from practical observations and scientific knowledge. These show us that natural ecosystems (and all or most of their component species) have had remarkable staying power when left more or less to their own devices. Over billions of years a stupendous variety of ecosystems have developed in terrestrial, freshwater, and marine regions. As these persisted and diversified in species, they acquired new ecological functions and extended themselves into all habitable parts of the Earth. The slow origination of these complex systems occurred despite (possibly helped by) major physical changes in the Earth's climate.

The notion that even today's natural systems change only very slowly through time (major human impacts are excepted) is encapsulated by the phrase "balance of nature." To analyze and describe the elements of the time-tested stability function is a formidable task, and there are many different theories that attempt to account for the persistence of natural systems, and their resilience and resistance to change over long spans of time. For a brief overview of the elements or "sub functions" of stability, please read the box titled Some Key Elements of the Stability Function on the opposite page.

20. Community Succession

The process of community succession is a major component of stability. It is separately classified here because of its importance, the enormous numbers of species involved, and the links of succession to geography and shifting climate. Succession is defined as a continuous directional change in an ecosystem at a particular site lasting dozens or hundreds of years. This change involves both colonization and extirpation of species in response to innumerable factors. The unique genetic characteristics of each species (function 18) determine whether or not it can invade and be present in a particular community or whether it will slowly become eliminated, although chance events play a part. The abundance of a species at different times within a

SOME KEY ELEMENTS OF THE STABILITY FUNCTION

1. Connectedness

The notion that "everything is connected to everything else" is an essential element of stability. How else can species meet their requirements? They must do so in consort with hosts of other species and through the functions of nutrient cycles, trophic levels, dispersal, and others, which involve most or all of them either permanently or from time to time.

2. Redundancy

Redundancy is the controversial notion that some species in an ecosystem may be surplus to its requirements and is discussed by Lawson & Brown (1993). A redundant species would be one that has seemingly identical functions in ecosystems as companion species. Thus, it is argued, the elimination of one of these species would not significantly change the characteristics of the ecosystem. For example; would a pond change dramatically if 2 species out of 20 species of single-celled green algae (all free floating) were lost? However, whether such redundant species are surplus in terms of their functions and potential functions is not provable. Genetic and chemical differences may well mean that opportunities exist to interact uniquely with other species. If so, redundancy may be a positive mechanism for buffering ecosystems against abrupt change—enhancing both short- and long-term stability.

3. Generalist Behaviour

When species are "generalists" or open to a variety of food sources and habitats, fluctuations in species numbers are dampened by spreading risk (Lawton and Brown 1993). The probability of extinctions is reduced. For instance, if a particular carnivore feeds on many different kinds of prey, its continuing presence in the ecosystem is less jeopardized by the extirpation of one of its food species than a carnivore that feeds only on one specific species. Similarly, a "generalist" bee not only enables numerous plants in a meadow to be pollinated (thus contributing to their survival), but is also less affected by the loss of a certain species of plant. Thus, the bee survives because of its wide foraging behaviour while the plants themselves survive because they, too, have developed flowers that accept almost any pollinator. Overall, stability in ecoystems is enhanced.

4. Keystone Species

A keystone species is one that has a disproportionate effect upon the persistence of all other species (Bond 1993). Keystone species are of different types: carnivores (mountain lions, killer whales, or sea otters), herbivores (snowshoe hares or caribou), competitors (aggressive exotics—such as the starling and purple loosestrife in North America, or dominant forest trees), symbionts (major pollinators or mycorrhizal fungi of dominant trees), earth-movers (earthworms or pocket gophers); plants that alter the fire regime (producing large amounts of burnable materials), and system processors (nitrogen fixers like lichens, alders, or legumes). Because each of these "keystone" species has a significant positive or negative effect upon the presence and abundance of many other species, they are crucial in determining the degree of stability or instability of the ecosystem.

5. Trophic Complexity

The complexity and length of food chains in a community may also have a bearing on stability. Communities with fewer and less complex food chains are usually more stable. According to some models (Lawton & Pimm 1980 in Begon *et al.* 1990), complex webs undergo such severe fluctuations that the extirpation of top carnivores is often a possibility. However, the extent to which such disruptions would affect species richness over large landscape regions is largely speculative.

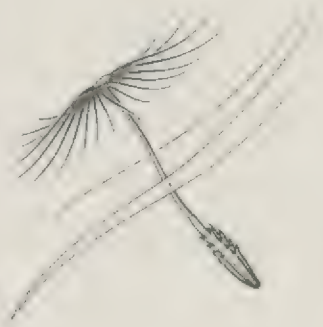
6. Complexity of Communities

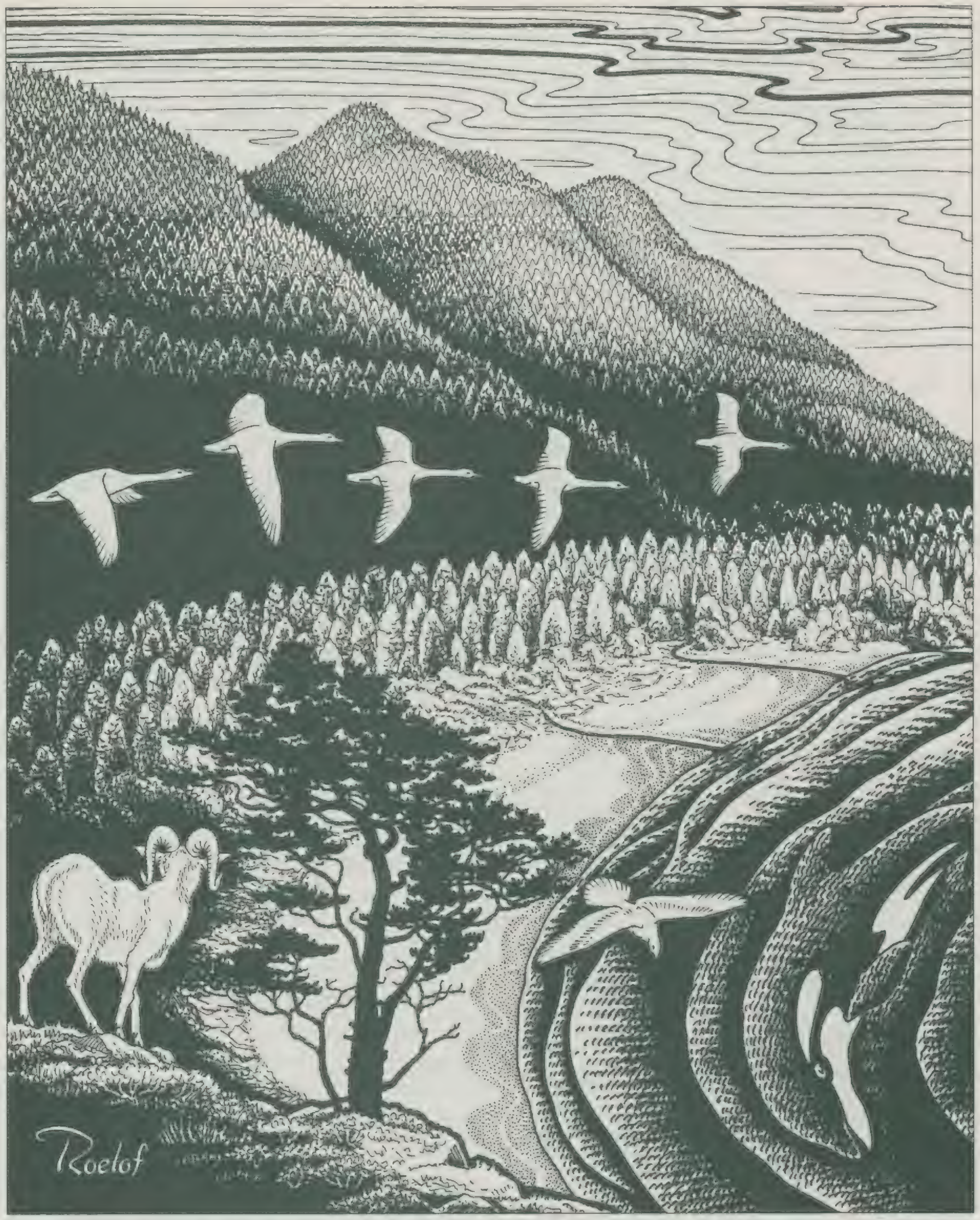
Modelling exercises predict that communities with few species are more stable than ones rich in species although the relationship is not clearcut. There appears to be strong agreement among ecologists that it would be far more difficult to restore a species-rich community (following major elimination of species) than a species-poor one (Begon *et al.* 1990; 801). Schultze & Mooney (1993; 507) note that "stability may decrease or increase with reductions in species number in a given system, and the effect may be different in temperate, tropical, and Arctic habitats."

7. Fire and other Disturbances

The effect of fire and other local disturbances upon ecosystem stability is evident when large landscape regions are considered. Repeated local fires or windthrow in ecosystems prone to fire (boreal forest, lodgepole pine forest, prairie) greatly increase the overall complexity of communities. Fire creates numerous successional stages that can support a wider variety of biota than if it were absent from these regions. The effect of fire on the stability of ecosystems has been described for Banff National Park (White & Pengally 1992) where Parks Canada has instituted a fire management policy to encourage biodiversity and maintain a permanent patchy disturbance (i.e. stable) regime.

The above described key elements of the stability function reveal to us the innate, self-realizing, and survival-driven complexity of interlocking ecological processes. These processes lie behind the continuing persistence and diversification of species and ecosystems over such vast spans of time.





HARMONY

Diverse, pervasive, and persistent, harmonies in nature exist at all levels necessary to maintain the whole. Harmony is the ultimate function of biodiversity and is the successful consequence of the workings of the other 20 functions.

successional sequence depends on genetic traits as well as the rate and timing of the return of a species to communities disturbed by fire, storms, insect herbivory, and other sudden impacts.

Many of the above described functions determine the details of community succession and help determine the species found in a particular ecosystem. For example, one such function is mutualistic symbiosis between plants and various soil microbes (Hawksworth 1992; Read *et al.* 1993) in forest communities. The presence or absence of mycorrhizal fungi can determine the kind of succession that is possible following major disturbances, such as clearcutting, deep soil fire, or agricultural practices. Plant species that do not require or prefer linkages with mycorrhizal fungi are obviously less constrained successionally.

Should major global warming become a reality, the genetic properties of individual species and their dispersal capabilities (function 8) will largely determine their success in colonizing new regions and altering the ecosystems present there as a result of earlier succession.

21. Harmony

Harmony is the ultimate function of biodiversity and is the successful consequence of the workings of the above described 20 functions. Diverse, pervasive, and persistent, harmonies in nature exist at all levels necessary to maintain the whole. They emerged over vast spans of time, and we can observe them in the shape, behaviour, and functioning of cells, individuals, populations, ecosystems, and in the ecosphere as a whole. In individuals, some obvious aspects of the harmony function are animal and plant form, the grace of animal movement, colours, and radial or bilateral symmetries. Even the world of microorganisms is full of harmonies of many types.

Another aspect of harmony is the innate capacity for hundreds—indeed, thousands—of life forms to live together "in relative harmony" through linkages, co-adaptations, symbioses, within a community or larger ecosystem. Many animals have evolved, exist and thrive in entirely different ecosystems during different parts of their life cycle or season. A brief description of the harmony function is provided by Augros and Stancieu (1988; 130-155). In short, wholeness, health, and integrity are all aspects of the innate harmony function.

Harmony cannot be separated from the abiotic part of biodiversity—the matrix of rivers, lakes, waterfalls, wind, pounding of ocean surf, landforms, clouds, and all other so-called abiotic conditions. Indeed, since the beginning of life, organisms have dramatically changed and shaped the characteristics of the ecosphere (Lovelock 1979, 1988; Schneider and Boston 1991). Harmonies appear to be the ultimate consequence of the workings of the laws of nature. The deeper origins of the pervasive persistence of harmonies in nature may be due to an innate drive of organisms to achieve maximum "self-realization" during the course of their lifetime, a concept similar to that described by Naess (1989).

Visualizing the obverse side of harmony helps us to think about this function. "Disharmony" or ugliness is created when organisms or ecosystems are reduced to fragments or parts. For example, a chain-sawed stump, severed hand, or headless body are certainly not harmonious. At the level of ecosystems, the expression of harmony is reduced and violated when a highway is cut through the wilderness, when a fully developed old forest is clearcut, when a river is toxified by a sewer or pulp mill, or when an oil spill baths a rich intertidal shoreline.

And finally, by recognizing harmony as the ultimate ecological function of biodiversity, we can come to realize that when contemplating the full meaning of biodiversity much more is at stake than the production of biomass or the struggle for survival of individuals.

FINAL COMMENTS

In conclusion, I want to summarize some of the ways in which knowledge of ecological functions can provide new, valuable insights about the intrinsic values of biodiversity and also how such knowledge of functions can be used to judge managerial success or failure.

The functions of ecosystems and their species working incrementally over billions of years have created the earth's ecosphere as we know it. For any piece of land or water today, one can ask: what functions are operating here? What functions have been lost (or gained) as a consequence of recent human activities? How serious is the change? Which functions can or should be restored? Thus, an understanding of functions can have a determining effect on management options and policy.

The Convention on Biological Diversity

An understanding of the importance of biodiversity functions and the consequences of loss of one or more of these functions in an area will lead to a greater

appreciation of the importance of the Convention on Biological Diversity. It is regrettable that the Convention's definition of biodiversity lacks the scientific precision that it deserves. The Convention defines biodiversity as *variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and ecological complexes of which they are part*. This definition mentions neither ecological functions nor biodiversity's inseparable abiotic matrix. This would not be the first time that the definition of an important concept was compromised as a result of a political decision-making process. However, the incomplete definition provided by the Convention should not deter anyone from understanding the full meaning of biodiversity and developing management policies and programs based on the full meaning.

The Land-health of Aldo Leopold

The list of 21 biodiversity functions casts an illuminating light upon Aldo Leopold's famous land ethic in which he stated: *A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise* (Leopold, 1949). It is a mark of Leopold's capacity to synthesize large amounts of ecological information (much of it based on direct observation and inference) that he was to anticipate the findings of ecological research and thinking of the next 50 years. Thus, over 40 years ago, Leopold had already concluded that stability and beauty were among the ultimate biodiversity functions (dependent upon all the other functions). In this article, beauty has been incorporated into harmony, which is a more inclusive, objective, and scientifically definable concept.

While bearing Leopold's land ethic in mind, one should briefly scan over the 21 functions in Table 2 and ask of each: is it right or wrong to preserve or destroy this function at a particular place or in a larger region? Knowledge of the functions can provide people with specific, relatively objective answers to Leopold's maxim on land-health. Thus, in areas where there has been a loss of species or ecosystems and their functions, there is corresponding loss in land-health. The link to management decisions and policy making should be obvious.

The Gaia Thesis

Many biodiversity functions have been interpreted as essential elements of the Gaia hypothesis (Lovelock 1979, 1988; Schneider & Boston 1989), which postulates that the ecosphere is a self-regulating homeostatic system in

Photo by Dr. Ronald R. Gimm

which the living and abiotic components interact to maintain a balanced, constant state. Primary production, oxygen production, sequestering of carbon dioxide, moderation of micro and macroclimate, stability, and some others are being studied for their role in this mechanism.

The Value of Norms/Standards of Biodiversity to Biological Resource Management

Knowledge of ecological functions makes it easier to understand what constitutes normal environments and to evaluate deviations. The rationales for norms in each of the five parts of biodiversity are provided elsewhere (Mosquin, Whiting and McAllister 1995, chapter 3) and are discussed by Leopold (1949). Because "wilderness" has persisted since the beginning of life, it is considered to be the most pervasive norm of the ecosphere. Hence, the survival of wilderness and its component species provides the only known scientifically demonstrable standards against which the success or failure of biological resource exploitation (forestry, agriculture, fisheries) and development can be judged.

I am not aware of any cases where managers of forests, fisheries, agriculture, or the advocates of development have ever carried out analyses of the deviations from planetary norms. But simple observations reveal that great changes in functions continue to take place. As a guiding light, managers can consider the observation of Thomas Berry (in Meeker-Lowry 1988) who noted that "the integral functioning of the natural world is taken as the supreme model of managerial success." Resource managers who wish to build biodiversity thinking into their decisions about land use, especially zoning, should find great value in the idea of biodiversity norms.

A key management question should be: how much biodiversity is needed to maintain the health of the biotic community and retain planetary norms? How much wilderness can be destroyed without severe

consequences to the system as a whole? Indeed, the answer to the question "Does biodiversity matter and how much?" may be critical to humanity's quality of life, future options, and security. The losses of species and ecosystems continue globally at an accelerating pace, and many parts of the world have already seen the elimination of most of their natural ecosystems.

Solbrig (1993; 111) noted that "much more research is needed to determine precisely and rigorously the role of biodiversity in ecosystem function," a statement with which few would disagree. But is research alone what is needed? A workshop held in March 1994 in San Diego, sponsored by the Scientific Committee on Problems of the Environment and organized by Dr. Harold Mooney of Stanford University, assembled what data were available (report by Baskin 1994). At the meeting a beginning was made to find some answers and point directions for priority research. But with the accelerating losses of biodiversity, the research material (i.e. the actual species and ecosystems) may not be around to provide the needed answers. As well, whatever the answers, humanity is saddled with a value system so intensely homocentric that the real value of vanishing species and ecosystems goes unrecognized.

People can count on the wilderness norms of the past with certainty, but will wild species and ecosystems survive in sufficient abundance to maintain the norms of our planet into the future? In Canada, as in other countries, there is a resistance to biodiversity conservation among resource managers, cultural leaders, many corporations, the "wise use" or "share group" movements, and most political leaders. A sad development is the emergence of a "green" language that misleads people into feeling that the conservation of biodiversity is being taken seriously. Will the tide be turned before most of the pieces are gone? I sincerely hope so.

ACKNOWLEDGEMENTS

I wish to thank scientists who have offered criticism and suggestions regarding both the functions and the framework presented here. In particular, Dr. Fred Schueler, Bishops Mills, Ontario; Don E. McAllister, Canadian Museum of Nature and Ocean Voice International; Stan Rowe, New Denver, B.C.; Geoff G.E. Scudder, Department of Zoology, University of British Columbia; Ernie Small, Agriculture Canada, Ottawa; and Clarence Frankton of Ottawa have provided thoughtful and sometimes challenging reviews. However, I take full responsibility for the ideas, groupings, and rationales provided here.

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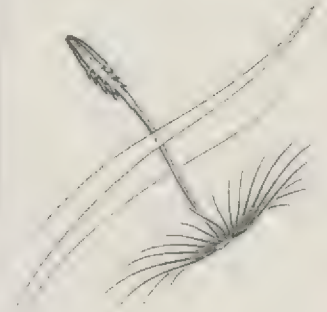

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SCIENCE'S NEW CHALLENGE:

Rebuilding Noah's Ark*

The current biodiversity crisis can be likened to that faced by Noah with threat of widespread flooding. The Convention on Biological Diversity is a blueprint for a new Noah's Ark to save the variety of life on Earth. [D.E.M.]

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We are told in Genesis, the first book of the Old Testament, that the patriarch Noah gathered in his ark two individuals of each living species to prevent them from disappearing forever in the Flood. Millions of years later, specifically in the summer of 1992, on the occasion of the Earth Summit, Canada and other countries set for themselves the same challenge that Noah accepted: the conservation of the world's biological diversity.

The challenge is considerable, for this project goes way beyond the "simple" gathering of individuals of each known species. The conservation of biodiversity means ensuring that living species and the ecosystems where they are found do not disappear, while taking into account the interests and the needs of the people who benefit from the use of all these resources. What we therefore have to do is ensure the survival of species–be they plant or animal, and whether living in natural ecosystems, urban areas, or agricultural zones. The survival of living species also means the survival of their genetic potential that has been used as a source of food, building materials and drugs, since time immemorial. In addition, they have been a source of spiritual and intellectual inspiration for humankind.

Multidisciplinary teams of scientists, business people, and politicians are already busy "building" a modern Noah's Ark. This time around, however, conservation areas and development policies adapted to particular regions will replace nail and board.

BUILDING THE ARK

In concrete terms, the building of a modern Noah's Ark involves numerous steps. Conservation areas where regional biodiversity can flourish have to be developed, either as parks or reserves, and perturbed ecosystems have to be planned anew and reorganized. Also listed on the builders' agenda is the development of standards for resource use—taking into account the impact of human activities on the environment. These standards, be they laws or policies, will have to combine land use and long-term resource use, which means that they will have to further sustainable development. This last step will form the frame of the ark on which development sites will be "nailed" in natural ecosystems, urban areas, and agricultural zones.

WHERE SHOULD THIS NEW ARK BE BUILT?

Deforestation of tropical zones is regularly placed in the first row of the prisoner's dock as far as the issue of the daily disappearance of living species is concerned. If the tropics are often used as an example to underline the scope of species disappearance, it is because of the plethora of species that are found there, whose existence

*translated from the French

we are just beginning to be conscious of. However, everything points to the fact that other anthropogenic activities also have an impact on the number of species living on our planet.

In fact, atmospheric fallout from industrial activities and resource overuse can also be found in that prisoner's dock. Consequently, the impoverishment of biodiversity becomes a world phenomenon. It is therefore everybody's responsibility to become involved and to adopt measures that will enable the biodiversity of their area to flourish, thus laying out the foundation of new Noah's arks throughout the world.

SETTING SAIL

The development of arks is not the only proof of the success of the world's biodiversity conservation project. We must be able to set sail whatever the "bad weather," be it natural cataclysms or man-made disasters. As one of its top priorities, the scientific body must devote itself to predicting the mechanisms underlying the reactions of the organisms to "bad weather."

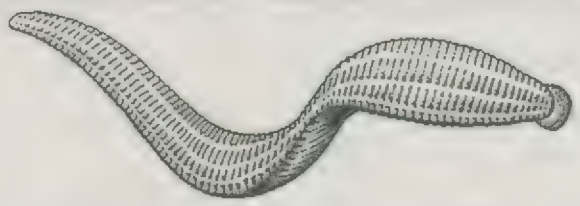
Scientists must develop the tools necessary to prevent the effects of disturbances, which are at times destructive to the biological diversity of ecosystems, by studying autogenic interactions (interactions between organisms) and allogenic interactions (interactions between organisms and their physical and chemical environment) more in depth. Thus, be it from experimental systems set up in the natural environment or in the laboratory, we must be able to evaluate and predict the effects of overfishing, nutrient loading from fertilization, and atmospheric pollutants on biodiversity. These environmental disturbances are among the worst "bad weather" that the Canadian Shield ecosystems, for example, will have to go through in the near future. But by undertaking species inventories, from the smallest ones like phytoplankton (microscopic algae living in the water column) to the largest ones, like whales, we are answering one of the greatest challenges ever faced by humankind; that is, the evaluation of the possible fluctuations of ecosystem biodiversity to environmental disturbances.

In short, it is the understanding of the relationships that determine community structures that will enable the arks, with their loads of enormous biodiversity, to sail safely and prevent them from being shipwrecked.

The Earth Summit reminded us of the importance of the ecological drama being played out at this moment throughout the world. The new challenge facing researchers around the world is now to develop tools adapted to every major area of the planet in order to prevent the often harmful impacts of environmental disturbances on biodiversity.

The complete success of the conservation of the world's biodiversity will depend on our capacity to transform the Earth into an immense Noah's ark. We have everything to gain by doing something now since we are all "in the same boat."

The complete success of the conservation of the world's biodiversity will depend on our capacity to transform the Earth into an immense Noah's ark.



INFORMATION AND TRAINING IN BIODIVERSITY:

The paradox of Noah's Ark

Scientific knowledge, and regionalized and global education and training are important tools in saving biodiversity. These will provide a basis for protected areas and overcoming some of our prejudices for and against certain species. [D.E.M.]

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An address presented in French on 17 May 1994 to the French Canadian Association for the Advancement of Science (L'ACFAS)—Montreal, Québec.

INTRODUCTION

The ecological awakening of the last 30 years has made us realize the appalling consequences of industrialization and economic development on the planet's environment. The metaphor, dear to Buckminster Fuller, that compares the planet Earth to a spaceship has become commonplace, and children are encouraged as early as grade school to love their planet and fight the pollution that threatens to destroy it.

We are discovering today that the development of humankind, at the planetary level, is leading to an accelerated disappearance of living species as well as to the loss of genetic diversity within those species. This discovery, widely popularized by the media, is all the more dramatic since we have been witnessing the birth of new biotechnologies over the past ten years, which give us a glimpse into the fabulous potential of the genetic make-up of living species. Michael Crichton's recent book, *Jurassic Park*, gives us an excellent idea of the effect that this discovery of the potential of biotechnologies can have on the human mind. Thankfully, science has certain constraints that magical thinking does not.

According to some authors, this current loss of biodiversity is beginning to look like an episode of massive extinction akin to the ones that occurred during glaciation or even such a catastrophe as that which occurred during the Cretaceous age (IUCN *et al.* 1991). This extinction is forcing us to rethink our understanding of the mechanisms of life and natural equilibriums.

Since the early 1980s, international organizations concerned with conservation have increasingly been promoting the protection of biodiversity as one of the fundamental priorities of conservation education. Unfortunately, there are a number of hurdles in the way of an efficient education about biodiversity. These hurdles are both scientific and conceptual, and they must be closely looked at before undertaking any educational action concerning the environment if any effective results can be expected.

BIODIVERSITY: A REALITY THAT IS DIFFICULT TO GRASP

Biodiversity can be defined as the variety, as well as the variability, of living forms and ecosystems in which all living organisms can be found. For scientists, biodiversity can be measured by looking at the genetic variation within the same species as well as the variety of species within different ecosystems, and even the variety of landscapes and plant associations in a given setting.

For the layperson, however, it is a reality more difficult to grasp. While we can readily appreciate the diversity of landscapes or higher animals, it is beyond our capabilities to evaluate the diversity of genetic forms or plant varieties—not to mention insects, arachnids, mycorrhizal fungi, or microscopic algae, which make up the majority of living organisms.

It is also difficult to grasp the reduction of biodiversity. Indeed, species do not usually disappear overnight. It is often at the end of a long process of rarefaction that the last representatives of a species find they can no longer resist the pressures of the environment. Also, the most discrete species, or those that are individually distinct, often disappear first without bringing much notable change to the landscape or "seascape."

Lastly, our modern world imposes on us a number of governing ideas, which depend on marketing objectives and industrial production imperatives. These governing ideas reduce the diversity needed for the satisfaction of human needs to a superficial diversity. Only a few varieties of plants and animals—those that are resistant to the difficult conditions of intensive agriculture and battery breeding—can meet the imperatives and constraints of industrial production and large-scale distribution. Also, there is a tendency to reduce the cultural diversity associated with the use of local varieties and traditional ways of using the natural resources. This loss of cultural diversity is accentuated by the spreading of a global mass culture.

Removed from any contact with their ecosystems and close environment, city-dwellers—who will represent more than 80% of humankind in the year 2025—can only learn about biodiversity through television, books, or visits to botanical or zoological gardens. Farmers, traditionally closer to genetic resources, must set their traditional knowledge aside and follow the recommendations of agronomists and seed vendors if they want their produce to reach the marketplace.

THE PARADOX OF NOAH'S ARK

If it takes exceptional technological skill to recreate even the simplest of ecosystems in a confined space on Earth, we can imagine the difficulties of spreading a significant biodiversity in an abiotic and abiogenic environment, on other planets, or in space.

The living world we are still exploring today is the result of three billion years of evolution, which has often been more destructive than constructive for many species. Indeed, competition is the primary method of natural selection. And there are always losers in competition, whether individuals, populations, or species.

We have only begun to realize both the finite nature of the planet and the quickening pace of the disappearance of those species we know best. Realizing that the majority of living species remain unknown to us, scientists are concerned with the effects of human activity on the millions of species they have yet to discover. Their concern is expressed through calls for the safeguard of endangered species, and these calls are repeated by environmental groups fighting for the protection of nature.

The motivation of those wishing to protect nature is legitimate in many ways: endangered species point out what might happen to our own species if we do not stop polluting the biosphere...our sources of food are limited to a small number of species, the genetic impoverishment of which risks making people more prone to infections and diseases...genetic engineering will enable us to discover a cure to our ailments in the unexplored biochemical wealth of unknown tropical plants...and so on.

By rushing to the rescue of endangered species, we pose as the saviour of biodiversity, just like Noah was to save the animals of all species (except the fish, of course) from the Creator's aquatic outburst of wrath. Once again our feeling of superiority toward nature is reinforced.

Ogrizec (1993) qualified this theme of protecting endangered species as "Noah's complex," which he summed up in these few words:

...in the face of an outside threat, man remains the only possible recourse for animals, their only chance of being saved from a certain death. (Translation)

Yet death is a rule of nature (Villeneuve 1992). Whether it is the death of individuals or species, nothing resists the passage of time. Life is a long succession of interspecific murders, and life itself poses a constant challenge to the principles of entropy, which is the measure of randomness or disorder in a system.

Species have always disappeared, but for natural causes. *Homo sapiens* appeared because other species had disappeared. We are ourselves, therefore, a natural factor in the disappearance of species. In protecting certain species from disappearing, we prevent others from reaching their full potential for development. In short, we are intervening in an evolutionary process.

The Biblical story of Noah's Ark does not mention the menu that was served at the captain's table during the 40 days and nights of the flood's duration...and even less the state of trophic or nutritional relationships between the animals during their forced cohabitation on the Ark.

Noah's complex is at the source of a paradox: protecting the status quo means protecting ourselves. But protecting ourselves (and the species we prefer) also means destroying other species. And this destruction is unavoidable to guarantee the daily survival of millions of people who certainly have the right to live.

Smallpox is a good example. By deliberately eliminating this species of virus from the face of the earth, look how much suffering and how many deaths we have saved humankind. Who will be the ecologist who will fight against the disappearance of the flu virus or a parasite worm causing onchocerciasis or elephantiasis? Would we ever find people to join a Society for the Protection of the Tapeworm?

To protect nature as it exists today also allows us to protect ourselves. By reducing the diversity of the living world, we reduce the possibilities of adaptation of the natural world in the course of its general evolution. In response to changes brought about by us, the reduction in biodiversity causes a reduction in our own capacity to fulfil the needs we have created for ourselves as a species in the course of history.

Noah's dilemma, that is, to chose between who will be eaten to guarantee the survival of the whole, or to protect the whole at the risk of seeing the captain and his boat perish, is the dilemma facing humankind today. How can we satisfy the needs of our current populations while respecting the carrying capacity of the biosphere?

BIODIVERSITY: A DIFFICULT CONCEPT TO EXPLAIN

Explaining biodiversity is not an easy task. There are a number of hurdles that must be overcome before we can claim success. These hurdles are related to the examples, beliefs, and real difficulties in understanding or managing certain types of situations. Herewith is a non-exhaustive list of these hurdles for the purpose of discussion.

Ignorance of the number of species and the role they play in the ecosystems

It is impossible at the present time to come up with an accurate and reliable number of the species living in the biosphere. The estimates range from 2 million to 10 million; some authors (May 1988) go as far as 50 million to 60 million, and a few to 100 million. This wide margin of discrepancy makes it difficult to give decision-makers an awareness of the importance of the problem. On the other hand, overly accurate numbers, such as those found in certain popular publications, do not withstand scrutiny.

In addition, as I indicated earlier, the role played by most species within the ecosystems is completely unknown. The relations of parasites, commensals, or symbiots can usually be understood through specific research. But the complexity of highly diversified ecosystems, such as mangroves, tropical forests, or coral reefs, makes it extremely difficult to describe the role played by each species or association of species. The complexity of the vital cycles of certain organisms prevents us from predicting the effect of their disappearance on the future of an ecosystem. Generally, only when the disappearance of a species or a group of organisms has become a fact, can we assess the consequences on the future of the ecosystem.

The generalized lack of knowledge of the population and decision-makers

The bases for explaining biodiversity are the same bases for explaining genetics, molecular biology, evolution, and ecology. Several of these sciences are barely accessible to the layperson and their vocabulary is esoteric. Popularization of these sciences is a challenge in itself, and the complexity of the relations involved does not lend itself to the reductionism and oversimplification we expect from the mass media.

The De Minimus syndrome

The *De Minimus* syndrome (from Latin, meaning "about the least") refers to the behaviour and beliefs characteristic of those who wish to function with the fewest means possible in a complex system. It could also be called "the cutbacks complex." This syndrome is based on the belief that a system can be deprived of most of its constituents and still function and provide the services expected of it.

Will anyone fight to protect the medicinal leech, *Hirudo medicinalis?*

This could be illustrated by the story of a man who decides to sell his blood and some of his organs for the purpose of obtaining an income. Each time he parts with an organ, he survives the operation, but his body becomes weaker. At the first infection, he is unable to mobilize his body's reserves because he has none left.

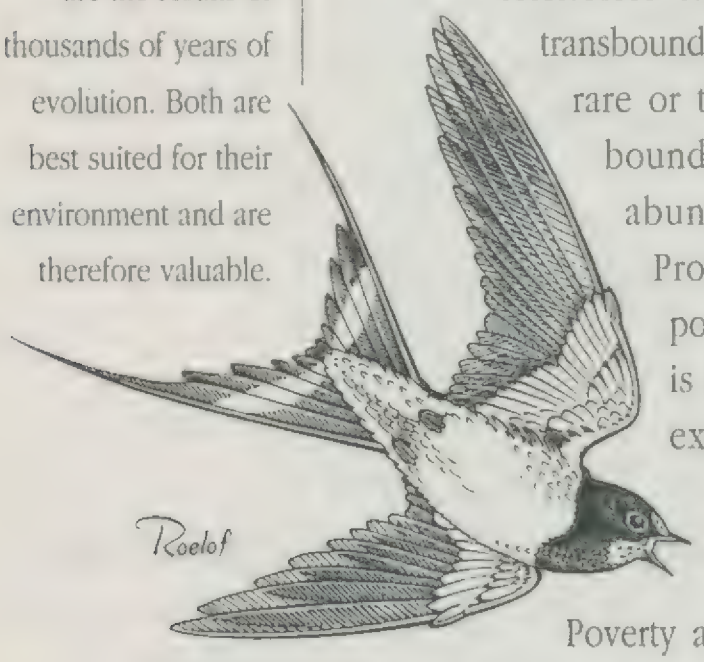
Unfortunately, this technocratic paradigm is common and tends to dominate at times of recession. In a world where we are about to confer an economic value on species, this viewpoint will undoubtedly be destructive. Thus, when a question is raised as to the impact of the disappearance of a species, there is usually someone who answers that it is of little consequence because everything will be pretty much the same afterwards. This type of thinking is common among our decision-makers who are usually ignorant of the value of diversity in their management models.

The lack of perspective—in time and in space—of our decision-making processes

Phenomena that have an impact on biodiversity cover periods ranging from a century to a millennium. The disappearance of the dodo bird (*Raphus cucullatus*), for instance, was followed by the near extinction of a precious tree (*Clavaria major*) in Mauritius two hundred years later. In the same way, the disappearance of certain pollinator hummingbirds or frugivorous bats will surely have an impact on certain species of tropical trees in an unforeseeable future.

Unfortunately, our decision-making processes are based on political territories and electoral mandates. It is all too easy to leave the consequences of our lack of vision to the next generation or to those living downstream or downwind from the sewer pipes or chimneys. In addition, protecting species on the basis of political territories can cause important biases. A transboundary species may be considered rare or threatened at the north of the boundary while it is still relatively abundant more to the south. Protection efforts on behalf of a population at the limit of its range is sometimes carried out at the expense of other, more fragile species.

Should we protect the mosquito or the swallow? The true beauty of both creatures is that they are the results of thousands of years of evolution. Both are best suited for their environment and are therefore valuable.



Poverty

Poverty and environmental deterioration go hand in hand: the consequences of the former make the latter inevitable. In several countries with highly diversified ecosystems, the living conditions force people to obtain the resources required for their subsistence from the natural environment at any cost, usually at the expense of the survival of certain populations or species of animals or plants.

No ethical stand regarding nature can allow us to overlook our ethical stand toward humans. Yet populations tend to grow faster in poor countries than in rich countries, and there is a tendency to push back the impoverished masses everywhere in the world at the fringe or in fragile areas. Therefore more and more people must satisfy their basic needs by drawing their sustenance from natural environments. In doing so, they exert pressure on the environments way beyond their carrying capacities.

A certain concept of beauty

It is much easier to arouse people's interest in protecting a mammal than in protecting a species of fish, amphibian, or reptile—not to mention an invertebrate. Seal hunting was an important source of income for fishermen in Newfoundland and the Magdalen Islands. Following an international campaign led by U.S., Canadian, and European groups and NGOs such as Greenpeace, the import of seal skins was forbidden in Europe in the 1980s. This campaign would certainly have been less successful had it been to ban fishing cod or ocean perch. Likewise, protecting the panda is a much more popular cause than protecting the rhinoceros or the crocodile.

Unfortunately, the general public has difficulty understanding the true beauty of nature in which each plant or animal is the result of thousands of years of evolution and that its adaptations make it the best suited for its ecosystem.

TOWARD A BETTER UNDERSTANDING OF BIODIVERSITY

It is difficult to develop educational themes focusing specifically on biodiversity because biodiversity falls within the wider theme of the environment. Yet several steps can be taken to improve the effectiveness of the educational themes regarding the environment in order to protect biodiversity. These steps need to be taken by various people, whether they be government agencies, researchers, or non-government organizations. Here are a few points to ponder:

- **We must clearly establish the equation "Habitat Protection = Wildlife Protection."**

Protecting one or several species or even a reintroduced species cannot be successful unless accompanied by the protection of the entire habitat.

- **We must regionalize environmental education.**

The problem with our civilization is abstraction. Environmental education must have regional roots and be based on regional realities. Most people have no idea of the diversity of the flora and fauna surrounding them and the problems affecting them. The MADIE (Matériel Didactique en Environnement) project launched in the Saguenay–Lac-St-Jean area of Quebec in 1990 is an example of the type of work that can be done. MADIE provides elementary and secondary schools in the area with environmental educational material that focuses on regional issues. Materials include teachers' guides, activity books, and videos, with a focus on threatened species and habitats. Started in 1988 by a group of volunteers supported by UNESCO and regional and provincial sponsors, the project serves as a model for other areas in Quebec and this year will begin a joint project with Burkina-Faso.

- **We must integrate the study of global changes into environmental education.**

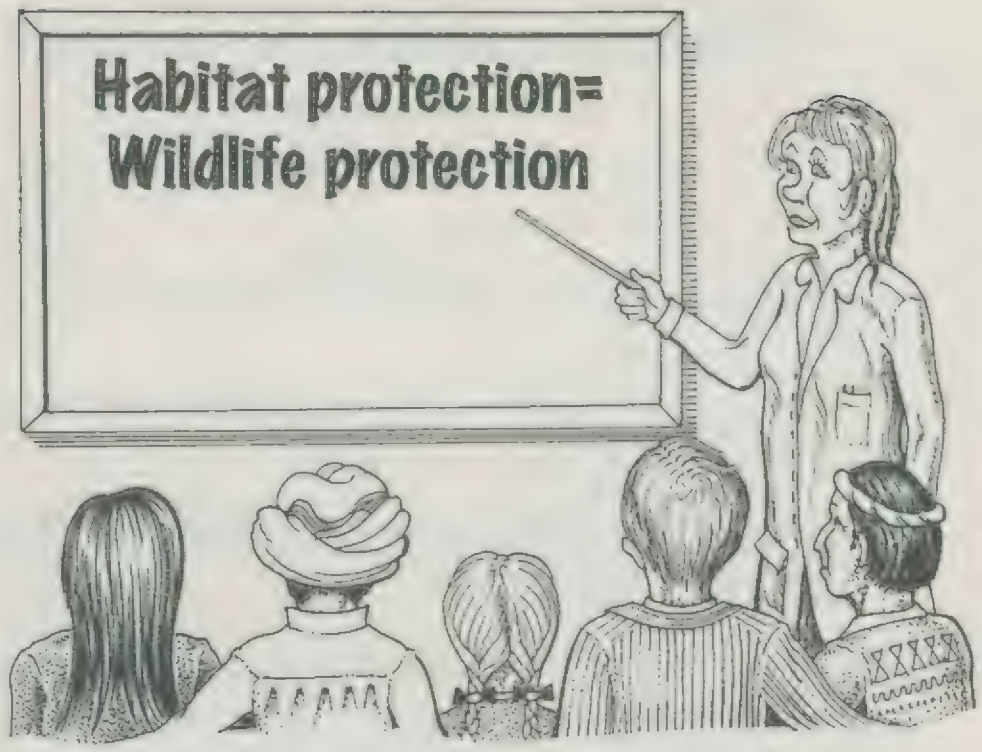
Most people have a static vision of their environment. By studying global changes, or the interactions that take place over thousands and thousands of years among large systems, humankind's actions within the biosphere can be put into perspective. By doing so, we can spark a reflection on sustainable development in the long term.

- **We must improve teacher training.**

Teachers, especially at the elementary and secondary levels, must be better trained in sciences and be given the proper teaching material to provide a useful education for the preservation of biodiversity.

- **We must create *in situ* genetic conservation centres with educational programs.**

Genetic conservation centres are a good way of preserving both different varieties within a genus of plants and certain plant or animal species. For example, *Les conservatoires botaniques* in France maintain certain varieties of apple trees. In one centre in the Alps, over 500 varieties of apples are grown. These conservation centres must be encouraged, but they must also develop educational programs, which will allow the public and students to realize the importance of biological diversity.



- **We must develop global conservation strategies where diversity is a crucial factor.**

The objective of preserving biodiversity must be integrated into any conservation strategy at all levels: local, regional, and national.

- **We must protect large portions of natural territory and rebuild ecosystems.**

Conservation of habitats and ecosystems must be carried out over portions of land large enough for the evolutionary processes to unfold naturally. In some cases, this means recreating ecosystems that will be repopulated with rare species. These areas can then be used to follow their evolution in time for educational purposes.

CONCLUSION

Questions concerning biodiversity and its conservation will be raised more and more often in the media and among teachers. Therefore, it is important to develop tools that will support quality education as well as effective conservation measures. In this way we can avoid losing certain species while we are busy studying how they can be useful to us.

To generate credible information and improve the effectiveness of education, we must bring about a change in the dominant representations concerning the place of humans within the biosphere. We must learn to value the notion of interdependence that cannot be dissociated from a true systematic approach.

If we hope to find a way to sustainable development, we must override the obstacles to a true understanding of the issues of conservation and biological diversity. Environmental education remains the most promising avenue for changing the attitudes and behaviours of people and decision-makers in this area.

Environmental education remains the most promising avenue for changing the attitudes and behaviors of people and decision-makers in the biodiversity area

SUGGESTED READING

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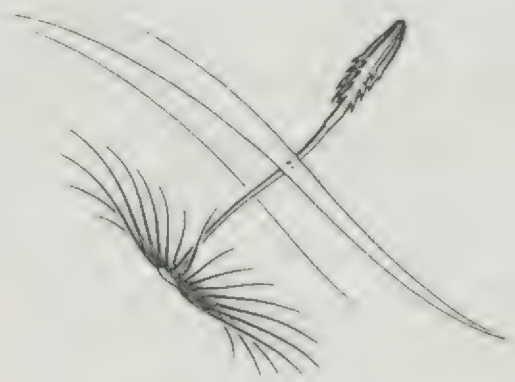

Diverse quotations

- ***We are reflected in all we see.***

  A phrase that can be posted in front of all sites of human activities. From a sign in window broken after the World Series riot in Vancouver, B.C. [Vancouver Sun, 16 June 1994, front page]

- ***The rule of no realm is mine, but all worthy things that are in peril as the world now stands, those are my care. And for my part, I shall not wholly fail in my task if anything passes through this night that can still grow fair or bear fruit and flower again in days to come. For I too am a steward. Did you not know?***

  J.R.R. Tolkien

- ***All terrestrial life ultimately depends on soil and water.***

  Daniel J. Hillel, 1991

- ***We know more about the movement of celestial bodies than about the soil underfoot.***

  Leonardo da Vinci

The application of interactive multimedia software in taxonomy and biological diversity studies

To study biodiversity and monitor changes in our biological environment, high quality taxonomic and distributional data are imperative. At present, access to species information and identification keys is limited because literature is scattered over a vast number of sources. Exchange of biodiversity data between researchers is hampered by the lack of universal documentation tools. The introduction of personal computers in biological sciences resulted in the creation of thousands of small and medium sized databases in hundreds of different incompatible formats. Modern multimedia computer techniques, allowing nearly unlimited storage of graphic information and text, will facilitate distribution of easily accessible data. The Linnaeus II software package for biodiversity documentation is an answer to these needs. It presents a universal tool for biologists to document biodiversity and exchange standardized data. Regularly updated electronic monographs on CD-ROM will form the basis for modern, fast, accessible libraries.

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INTRODUCTION

In recent decades, awareness of the need to conserve the biosphere has spread from a few concerned environmentalists to a vast group of scientists, policy makers, and politicians. The destruction of habitats through human activities, and the pace at which this takes place on a worldwide scale have finally evoked plans to "do something about it." Although this is a good sign, we must realize that we are only beginning to understand the size of the problem of an eroding biosphere, and we are still far from knowing how to find good ways of keeping our precious planet in healthy shape.

The key word is biodiversity. In most contexts biodiversity means the knowledge of biological diversity—in other words, information on the numbers (and variability) of species inhabiting areas, on their habitats as well as their interactions in ecosystems. This encompasses knowledge from a great number of specialized fields in modern biology, yet few universities dedicate study programs to this highly complicated field of biology.

A common way to assess biodiversity is to measure species richness, and the distribution of those species over a predefined number of higher taxa (May 1992; Pielou 1966; Wilson 1992). In nearly all cases, ecosystem interactions are left out of these equations as they are too complex or insufficiently known to include. Such equations are risky; they may lead either to protection of an area and environmental measures, or to the predicate "no biological value" and subsequent destruction. The problem is how to determine which species are important to measure or monitor biodiversity. Taking into account that of the estimated 30 million to 100 million species (May 1988) that inhabit the Earth, we have named and described only about 1.8 million, it is clear that selecting so-called key taxa in biodiversity studies is, at the least, questionable.

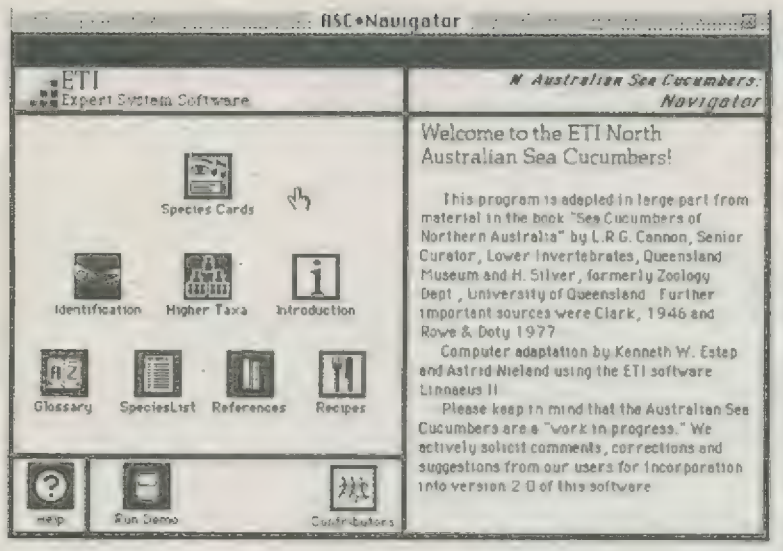
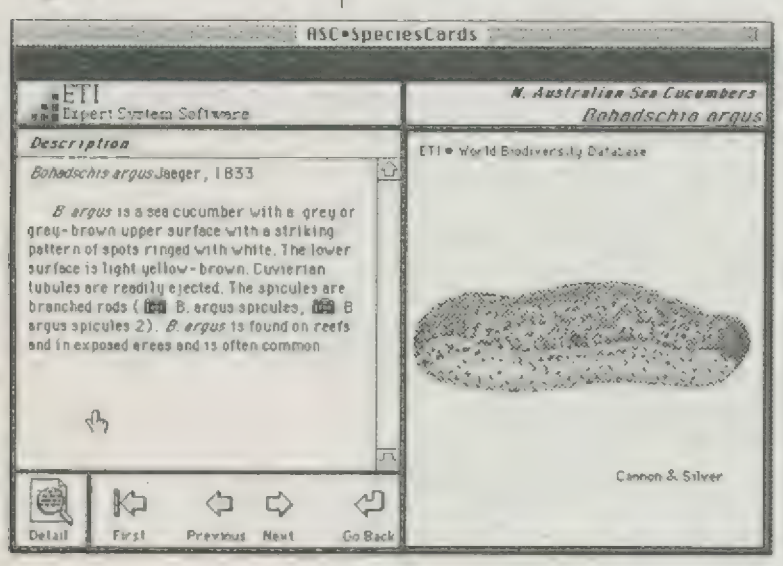
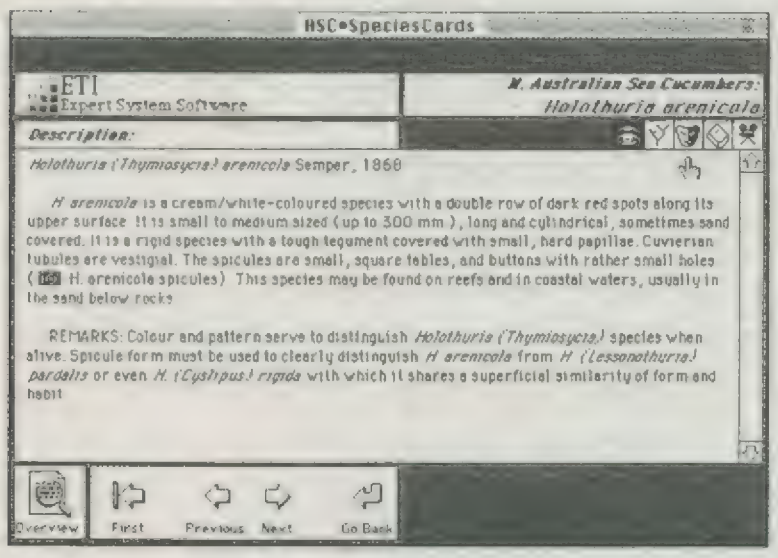

ASC•Navigator
ETI
Expert System Software
N. Australian Sea Cucumbers:
Navigator
Welcome to the ETI North Australian Sea Cucumbers!
This program is adapted in large part from material in the book "Sea Cucumbers of Northern Australia" by L.R.G. Cannon, Senior Curator, Lower Invertebrates, Queensland Museum and H. Silver, formerly Zoology Dept., University of Queensland. Further important sources were Clark, 1946 and Rowe & Doty 1977.
Computer adaptation by Kenneth W. Estep and Astrid Nieland using the ETI software Linnaeus II.
Please keep in mind that the Australian Sea Cucumbers are a "work in progress." We actively solicit comments, corrections and suggestions from our users for incorporation into version 2.0 of this software.
Species Cards
Identification
Higher Taxa
Introduction
Glossary
SpeciesList
References
Recipes
Run Demo
Contributors

Figure 1

All biodiversity studies have to be based on good taxonomy. Only reliable identifications will render high quality datasets on species diversity. Compared to the terrestrial environment, marine biological sciences are even further from having a complete overview of ocean biodiversity and ecosystem structures. In general, what is known about a species is spread over a huge amount of scattered literature, and accessing these data is time consuming. There is an increasing need for accessible and reliable information on all known species and a strong desire to strengthen in-country user friendly biodiversity databases (Braatz *et al.* 1992). A universal tool for biodiversity documentation is needed to further science and make existing knowledge fast accessible.

Figure 2


ASC•SpeciesCards
ETI
Expert System Software
N. Australian Sea Cucumbers
Bohadschia argus
Description
Bohadschia argus Jaeger, 1833
B. argus is a sea cucumber with a grey or grey-brown upper surface with a striking pattern of spots ringed with white. The lower surface is light yellow-brown. Cuvierian tubules are readily ejected. The spicules are branched rods (B. argus spicules, B. argus spicules 2). B. argus is found on reefs and in exposed areas and is often common
ETI • World Biodiversity Database
Cannon & Silver
Detail
First
Previous
Next
Go Back


ASC•SpeciesCards
ETI
Expert System Software
N. Australian Sea Cucumbers:
Holothuria arenicola
Description:
Holothuria (Thymiosycia) arenicola Semper, 1868
H. arenicola is a cream/white-coloured species with a double row of dark red spots along its upper surface. It is small to medium sized (up to 300 mm), long and cylindrical, sometimes sand covered. It is a rigid species with a tough tegument covered with small, hard papillae. Cuvierian tubules are vestigial. The spicules are small, square tables, and buttons with rather small holes (H. arenicola spicules). This species may be found on reefs and in coastal waters, usually in the sand below rocks.
REMARKS: Colour and pattern serve to distinguish Holothuria (Thymiosycia) species when alive. Spicule form must be used to clearly distinguish H. arenicola from H. (Lessonothuria) pardalis or even H. (Cystipus) rigida with which it shares a superficial similarity of form and habit.
Overview
First
Previous
Next
Go Back

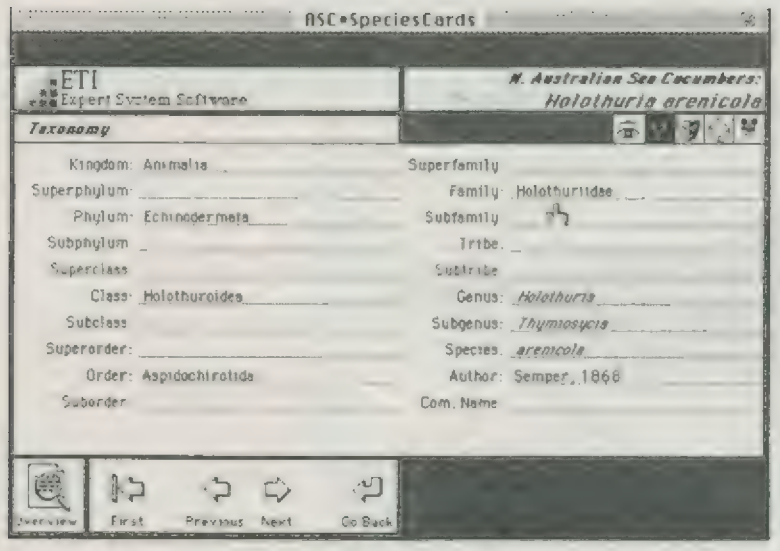


Figure 3

The only answer to this growing demand for directly accessible biological data is a universal, standardized, computer-based biodiversity information system. This system must be flexible enough to cope with and incorporate the many small, limited-scope databases in existence and must have the potential to produce regional master databases (Bisby 1993). For determining species composition, fast, standardized, and universal identification tools are needed, based on experts' knowledge to ensure high quality of data. Once a good inventory is established, monitoring studies can start to follow and document changes. For monitoring studies, reliable identifications are imperative to compare datasets between different working groups and geographical areas, especially when one aims to compare biodiversity values (Raven and Wilson 1992).

A new computer approach for biodiversity surveys is the answer. By using computer tools and modern interactive multimedia technology, it is possible to create easy to use and cheaply updatable identification and information systems (Estep *et al.* 1989; Estep *et al.* 1993; Schalk 1992) that can be distributed to biologists worldwide. By including simple Geographic Information Systems (GIS), that run on PCs and let one depict and analyze different sets of mapped data, distribution data can be stored and compared as well. In this article we discuss the possibilities and application of such a system as a basic tool for biodiversity documentation.

THE EXPERT CENTER FOR TAXONOMIC IDENTIFICATION

Taxonomy and systematics form the basis for most biological sciences. Especially in the context of biodiversity studies and biomonitoring of ecosystem changes, good taxonomy is an absolute necessity for obtaining reliable results. Despite this, the number of taxonomists is decreasing (May 1990) and the documented species information and identification keys are difficult to access as they are scattered over a huge amount of literature (Schalk 1992). Computer tools are the answer to preserving and exchanging knowledge (Pankhurst 1991).

The Expert Center for Taxonomic Identification (ETI) is a non-profit organization at the University of Amsterdam "for and by taxonomists." The center was set up in 1990 with support from the Dutch government, UNESCO, and the University of Amsterdam with the goal of developing novel interactive multimedia software for biodiversity documentation and species identification.

ETI has developed Linnaeus II, a user-friendly, easy to handle, universal biodiversity software operating system, or shell. Linnaeus II allows specialists to store information on species in the form of text, pictures, videos, and sounds in a standard and exchangeable format using their own PC (Schalk 1992; Estep *et al.* 1993). More importantly, this shell allows for the construction of "smart" (expert) identification systems, giving both specialists and laypeople fast access to the multimedia species information. The Linnaeus II system has various help functions on-line, describing the

character/states in text and graphics as well as instructions on how to use them. This opens up taxonomic keys to laypeople and students and would allow these programs to be used as a modern teaching tool.

The Linnaeus II system was built using extensive feedback from ETI's international taxonomy networks. It is designed to be used on relatively simple PCs. It has been released for Macintosh platforms, and a similar Windows version will be available in 1995. ETI also aims for incorporation of existing databases. The whole system is structured in such a way that data can be transported to other formats when needed. This also guarantees sufficient flexibility for the future. Linnaeus II is an excellent, user-friendly tool for biodiversity documentation. It allows the user to concentrate on the science instead of on how to operate the program.

A BIODIVERSITY INFORMATION SYSTEM: LINNAEUS II

The Linnaeus II program contains six major sections as shown on the navigator card in Figure 1: databases for species information and higher taxa, the IdentifyIt program for identification, a references database with all relevant literature, a glossary section (with all terms), and an introduction section (with general information on the group and methodology). All parts are fully multimedia and may contain text, photographs, sounds, and videos. The simple graphic user interface and hyperlink system guarantee easy point-and-click navigation through various parts of the program.

The species database looks like a filecard with an overview picture of the species on the right and an abstract description on the left (Fig. 2). From this point it is easy to page through the species cards for quick comparisons (Fig. 2, top). A click on the detail "button" leads to the "detail card" of the species database (Fig. 2, middle), from which the various information fields can be accessed (button icons on the right side). There are fields for the description (with chapters for taxonomic, description, diagnosis, reproduction, ecology, practical importance), taxonomy (listing all higher taxa names which are hyperlinked to give access to the higher taxa database), synonyms (allowing searches on old names or common names), references (specific to this species), and multimedia clips (listing all illustrations, sound files, videos, which can be accessed by a simple mouse click) (Fig. 2, bottom).

The higher taxa database is similar to the species cards with the same functionality but storing information on higher taxa such as family, order, class etc. Both these databases can be approached directly from the navigator section (Fig. 1), but also through free text search functions or from the Identification program.

The IdentifyIt section (Fig. 3) is a multiple entry approach to identification using the computer's power to search and compare. Instead of a rigid binary choice system that one has to follow step by step, in IdentifyIt a data matrix is used to identify a species. The user has a free choice to select any character (Fig. 3, top). Every character has a number of states, one or more states may be chosen, or even "unknown" may be selected. Characters and states are linked to descriptive texts, pictures, videos or sounds where appropriate, which can be called up by a button click. Once a choice has been made, the program sorts the species list in order of probability, shown as hit percentages. A click on the species name leads to the species database for a quick check, after which one can return to the identification program. It is also possible to compare species in the "hit list" for both common and exclusive characters (Fig. 3, middle). This way of identifying has great advantages compared to the conventional, printed, and rigid dichotomous keys, as it allows the user to start with any known or available character. Thus, even damaged specimens may be identified as the system also works with incomplete character/state sets and answers with a list of probable species. It is also possible to have the software list all characters and states for each species (Fig. 3, bottom).

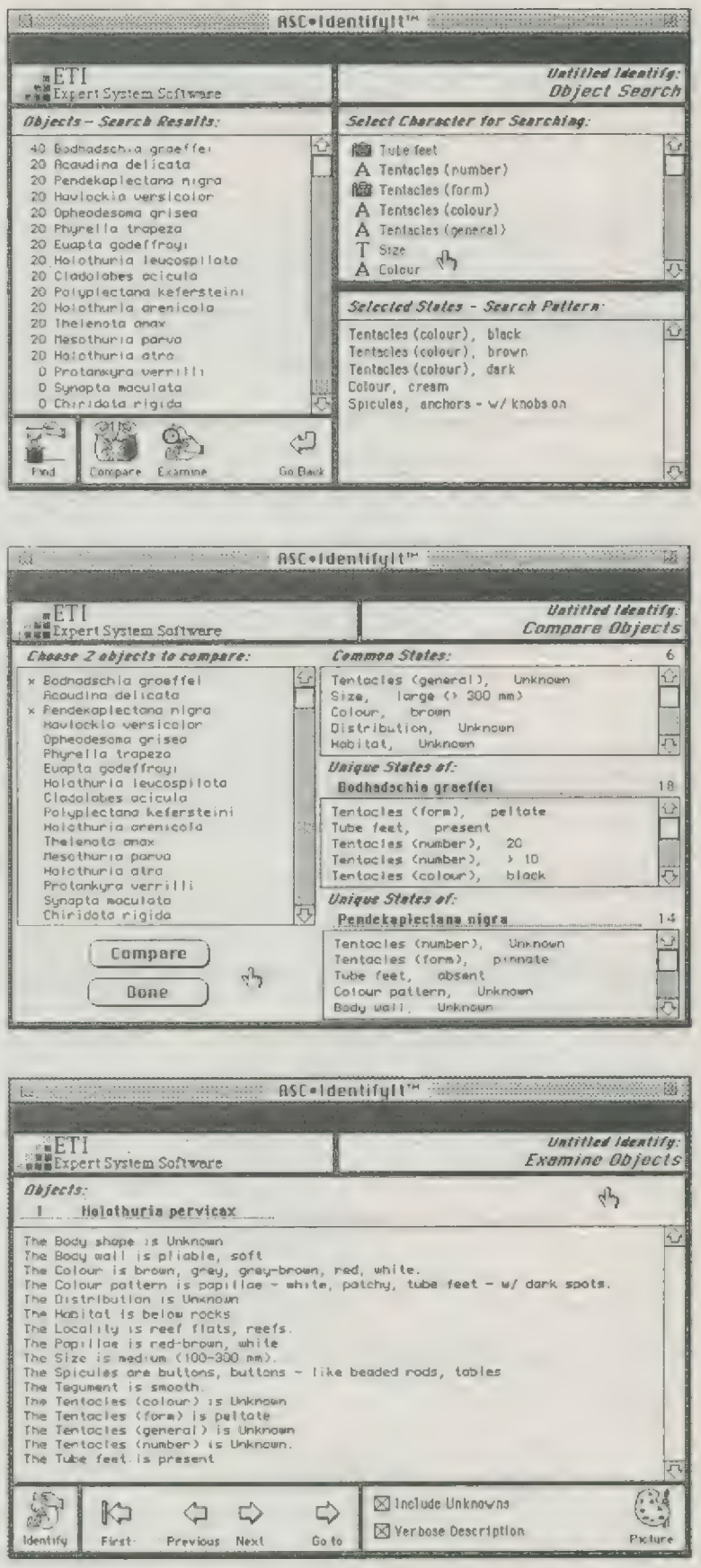
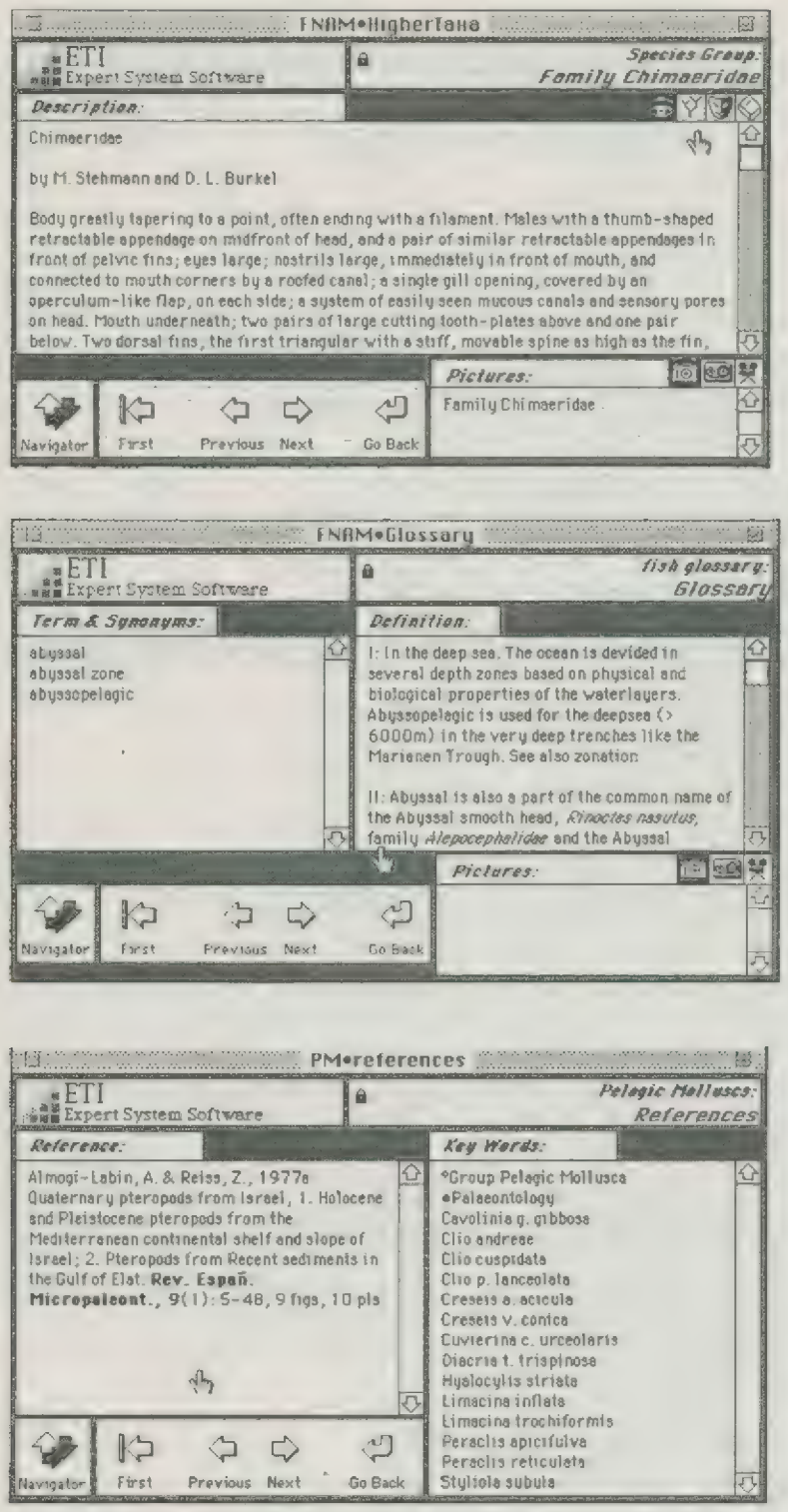


Figure 3

There are several support programs in Linnaeus II. The glossary part (Fig. 4, middle) was built in to allow to


FNAM•HigherTaxa
ETI
Expert System Software
Species Group:
Family Chimaeridae
Description:
Chimaeridae
by M. Stehmann and D. L. Burkel
Body greatly tapering to a point, often ending with a filament. Males with a thumb-shaped retractable appendage on midfront of head, and a pair of similar retractable appendages in front of pelvic fins; eyes large; nostrils large, immediately in front of mouth, and connected to mouth corners by a roofed canal; a single gill opening, covered by an operculum-like flap, on each side; a system of easily seen mucous canals and sensory pores on head. Mouth underneath; two pairs of large cutting tooth-plates above and one pair below. Two dorsal fins, the first triangular with a stiff, movable spine as high as the fin,
Pictures:
Family Chimaeridae
Navigator
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FNAM•Glossary
ETI
Expert System Software
fish glossary:
Glossary
Term & Synonyms:
Definition:
abyssal
abyssal zone
abyssopelagic
I: In the deep sea. The ocean is devided in several depth zones based on physical and biological properties of the waterlayers. Abyssopelagic is used for the deepsea (> 6000m) in the very deep trenches like the Marianen Trough. See also zonation
II: Abyssal is also a part of the common name of the Abyssal smooth head, Rinoctes nasutus, family Alepocephalidae and the Abyssal
Pictures:
Navigator
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Go Back
PM•references
ETI
Expert System Software
Pelagic Molluscs:
References
Reference:
Key Words:
Almogi-Labin, A. & Reiss, Z., 1977a
Quaternary pteropods from Israel, 1. Holocene and Pleistocene pteropods from the Mediterranean continental shelf and slope of Israel; 2. Pteropods from Recent sediments in the Gulf of Elat. Rev. Españ. Micropaleont., 9(1): 5-48, 9 figs, 10 pls
*Group Pelagic Mollusca
•Palaeontology
Cavolinia g. gibbosa
Clio andreae
Clio cuspidata
Clio p. lanceolata
Creseis a. acicula
Creseis v. conica
Cuvierina c. urceolaris
Diacria t. trispinosa
Hyalocylis striata
Limacina inflata
Limacina trochiformis
Peraclis apicifulva
Peraclis reticulata
Styliola subula
Navigator
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Figure 4

define and describe specific terms used within a taxonomic group or to explain about special methods. This help function increases ease of use for users relatively inexperienced in a certain taxonomic group. The terms database has fields for the term name and synonyms, description, and a multimedia field for illustrations. All text in Linnaeus II is "hot" through hyperlinking: clicking on an unknown word starts a search in the glossary section of the program. Also, special methods, for example, conservation or measurements, can be detailed in this illustrated glossary. The reference section (Fig .4, bottom) is a literature database with fields for key words, title, author, journal etc.

The introduction section also has a supporting function. It allows the specialist who constructs the program to explain the taxonomic groups covered, and its systematics, but also to provide the user with information on methodology. As videos can be included it is possible to give short lectures or instructions. These features add to the electronic monograph a versatile teaching tool, thus broadening its use and enhancing the applicability of the information.

A PC based GIS system "MapIt" is currently being developed by ETI to store distribution data. At the moment, distribution maps are stored as pictures, but in MapIt it will be possible to overlay distributions of several species, study species diversity in a certain area, or compare distribution patterns. MapIt will have various levels of resolution to enable storage of distribution patterns in detail as well as on a worldwide basis.

All sections of the Linnaeus II program are linked, enabling the user to move back and forth through the program whenever needed. Entering data is controlled from a pull down menu and keyboard commands. Special functions like "cloning" allow the user to duplicate a species record and a selected number of fields; this is very handy in making a new species record of an almost similar species. Like all other database programs Linnaeus II has a number of search functions for access to textual information in any number of fields or program sections.

INTERNATIONAL TAXONOMY NETWORKS

Creating these types of electronic identification and information tools is an expert's job. To build biodiversity databases ETI works together with UNESCO to set up and support both regional and international networks of specialists who use the Linnaeus II software shell for local database building. Working with these networks ensures standardization and quality control of the data. Specialists who become ETI partners receive the Linnaeus II software package for Biodiversity Information free of charge. The specialists send back the entered species data on a half-yearly basis. At ETI the various information sets are compiled and submitted to a review procedure similar to scientific journals. Completed sets (on a particular taxonomic group or geographic area) are disseminated on CD-ROMs. The CD-ROMs will be free for the authors who composed the programs, while others pay costs of production.

ETI also offers technical support in importing biological data from existing species databases to the Linnaeus II shell, or general support with scanning and entering data in printed form. The thus formed basic program can then be updated by the specialists before publication on CD-ROM.

The datasets will be updated regularly by the international taxonomy networks. At present ETI is working with about one thousand specialists all over the world, who together are building a marine biodiversity database that is being published literally "bit by bit" on CD-ROM. ETI stores all information in one big World Biodiversity Database in Amsterdam. This database will be available on-line to all scientists in a later stage.

BIODIVERSITY INFORMATION SYSTEMS

ETI applies the Linnaeus II shell to electronically publish and distribute species monographs or topic oriented subsections. In 1994 ETI will release six interactive multimedia titles on marine biology: Fishes of the Northeastern Atlantic and Mediterranean (+1300 species),

Sea Cucumbers of Northern Australia (+90 species), Marine Planarians of the World (+80 species), Pelagic Molluscs of the World (+280 species), Marine Lobsters of the World (+150 species), Sea Mammals of the World (+130 species). Other fields that will be covered are: fungi, yeast, timber trees, or regional data sets such as higher plants of Indonesia. Educational (student) titles are also published. They include "Five Kingdoms, a key to the phyla of life," and the "Protoctista glossary."

All these information and identification programs will be disseminated on compact disk (CD-ROM) for both Macintosh and Windows platforms. As they all have the same "Linnaeus II" format, their user interfaces and program structures are similar, warranting the same easy access to every program. Moreover, because the data are stored in a standard format, it is possible to combine the datasets so users can construct an electronic library that fits their needs.

CD-ROMs can contain huge sets of data (up to 650 Mb), including thousands of full color pictures and drawings, but also instructive videos. CD-ROMs are cheaper to produce than printed works, especially when full color images are needed, and can therefore be regularly updated when data sets are extended. Easy distribution (mailing costs are minimal) guarantees that all scientists can have access to the most up-to-date tool for their biological research.

CONCLUSION

We expect that through the use of this modern computer-based biodiversity documentation tool, species information can be made available and directly accessible on a worldwide scale. It will enhance fast data exchange amongst all scientists. It is only through getting the taxonomic basis right that we can start to understand and value biodiversity.

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One CD-ROM can contain up to 650 Megabytes of information, including full-color pictures, drawings, and videos.

BIODIVERSITY AND THE WORLD BANK:

Who should control genetic resources?

The text that follows was written and signed by numerous NGOs attending the Second Session of the Intergovernmental Committee of the Convention on Biological Diversity (ICCBD), and submitted to governmental delegations on 26 June 1994. The environment and development NGOs who attended the session in Nairobi (20 June - July 1994) have revealed that the World Bank intends to take control of the Consultative Group on International Agricultural Research (CGIAR). These collections, comprising almost half a million samples of precious crop biodiversity, were donated by farmers in developing countries. The samples represent the world's most important stock of unique breeding materials to improve world food production. According to the NGOs, the Bank is not keen on seeking intergovernmental authority over the genebanks, but wants trusteeship itself.

ISSUES

The Intergovermental Committee on the Convention for Biological Diversity's commitment to resolve the problem of ex-situ germplasm collections gathered prior to the coming into force of the Convention (Resolution 3) is being circumvented by a World Bank initiative to take over the Consultative Group on International Agricultural Research (CGIAR) and its massive genebanks.

IMPLICATIONS

More than half a million unique crop germplasm accessions—possibly the largest collection of socially- and economically-critical biomaterial in the world—is about to become an "asset" of the World Bank.

Virtually all of this material was donated by farmers and rural societies in developing countries. The World Bank is also negotiating with the new World Trade Organization (WTO) to make special provisions for access to the CGIAR genebanks under the terms of the GATT-TRIPs accord.

RECENT DEVELOPMENT

An initiative that would have brought the CGIAR genebanks under intergovernmental authority through a Food and Agriculture Organization (FAO)-CGIAR agreement was thwarted three weeks ago when the World Bank, which chairs the CGIAR, said it wanted to review the deal even though it had already been approved by all parties. Subsequently, Bank officials let it be known that they are holding separate discussions with the WTO and that they consider as "foolhardy" the arrangement through FAO that would for the first time have given policy control to the Third World.

BACKGROUND

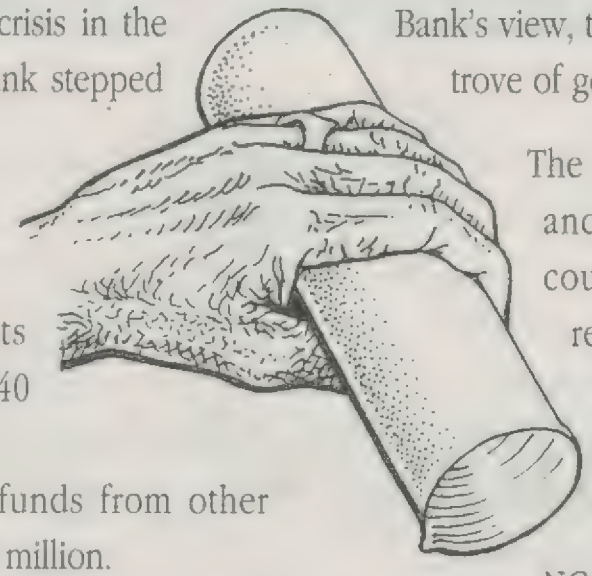
Under pressure from industrialized countries during the May 1992 negotiations that led to adoption of the Convention, *ex situ* germplasm collections gathered prior to the coming into force of the Convention were dropped from the Accord. However, recognizing the extreme importance of these collections, Resolution 3 of the Nairobi Final Act calls for solutions to this matter and that of Farmers Rights to be developed through the Global System on Plant Genetic Resources (FAO).

Subsequently, in 1993, the member states of FAO endorsed a process of negotiations with CGIAR intended to place the half million germplasm accessions under the policy control of the intergovernmental Commission on Plant Genetic Resources. The clear intent, for both FAO and CGIAR, was that this legally-binding agreement be the first step toward the development of a draft protocol for agricultural biodiversity for submission to the Conference of Parties.

By May 1994, the legal agreement had been accepted by FAO and by the relevant CGIAR bodies. Only formal approval was needed when the CGIAR's financial (as different from germplasm) donors, the industrialized countries, convened three weeks ago.

The Canadian Museum of Nature is pleased to provide an open forum for diverse viewpoints even though they may not represent the views of the Museum itself. Comments on these viewpoints are encouraged. Please mail or fax them to the editor (address on inside front cover).

In the context of the worst budgetary crisis in the 23-year history of CGIAR, the World Bank stepped in with a number of linked initiatives:



- Bank officials announced they were "forgiving" outstanding CGIAR debts.
- The Bank offered to increase its normal grant to the CGIAR to US$40 million.
- The Bank offered to match new funds from other donors up to a combined total of US$60 million.
- Finally, the Bank announced the creation of a new US$2.5 billion (over five years) fund for national agricultural research linked to CGIAR.

The Bank had some other announcements:

- For the first time in its 23-year history, the formation of a CGIAR Steering Committee chaired by the Bank.
- The appointment of another Bank official as Chair of the new Finance Committee of CGIAR.
- The Bank scuttled ratification of the FAO-CGIAR agreement and announced that it would provide leadership in this matter.
- The Bank would consult the World Trade Organization regarding the intellectual property provisions in GATT and the disposition of CGIAR germplasm.

In early June, CGIAR officials confirmed to enquiring NGOs that (1) the Bank was indeed in conversation with the WTO; and (2) the Bank was "not enthusiastic" about an agreement through FAO, with the Biodiversity Convention. In a letter to one NGO dated 16 June 1994, Ismail Serageldin, Vice President of the World Bank and the new Chair of the CGIAR, stated that "It would be foolhardy to lock into agreements" (related to CGIAR germplasm) within the next few years.

ANALYSIS

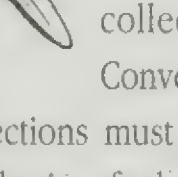
The World Bank is not a legitimate custodian of or policy maker for genetic resources donated by developing countries. The Bank is not governed on the basis of one nation–one vote and has never been accused of being sensitive to the needs of the Third World. The Bank's intent is to prevent intergovernmental control.

The Bank sees the CGIAR as a major instrument for the imposition of its agricultural programmes and policies and as an important private sector technology conduit. In the Bank's view, the CGIAR's major asset is its vast treasure trove of genetic materials.

The CGIAR has no collective legal identity and is merely a "club" of industrialized countries, financial donors who do not represent the interests of the donors of germplasm.

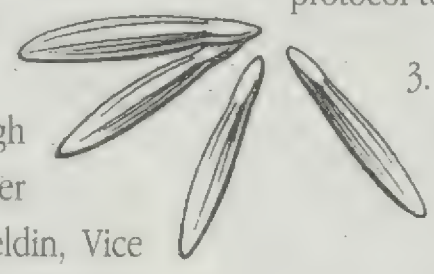
RECOMMENDATIONS

NGOs meeting in Nairobi on 18-19 June 1994 recommend the following:



1. The ultimate control of *ex situ* germplasm collections held outside of the country of origin, whether collected before or after the coming into force of the Convention on Biological Diversity, must rest with an intergovernmental body governed by the principle of one nation–one vote and with full recognition of farmer's rights.

2. The critical social and economic importance of the genetic materials within biodiversity that nurture people—including animals, plants, and microorganisms used for food, fibre, pharmaceutical and other purposes—should be recognized through a protocol to the Convention.



3. Recognising the particular situation of the CGIAR and its *ex situ* germplasm collections gathered both prior to the Convention and since, it is clear that these collections must come under the intergovernmental authority of a body as described in 1. above.

4. Therefore, the initiative by the World Bank to take control of the CGIAR genebanks should be rejected, and the FAO-CGIAR agreements should be concluded expeditiously.

5. Ultimately, the genetic resources held in the CGIAR genebanks, as well as all other *ex situ* collections, should come under the rules of the Convention. We urge the FAO to continue developing proposals on how to do so—as requested by Resolution 3—as soon as possible.

This material came from PeaceNet, a non-profit progressive networking service. For more information, send a message to peacenet-info@igc.apc.org

Biodiversity news

New U.S. program aims to halt extinction of taxonomists

Retirement of taxonomic specialists, shifts in academic recruitment and staffing, and reductions in graduate training all conspire to diminish the knowledge that is needed to answer what the National Science Board has labeled a global biodiversity crisis ("Loss of Biological Diversity: A Global Crisis Requiring International Solutions", NSB 89-171). The rate of "extinction" among professional taxonomists led a National Science Foundation (NSF) task force to call for enhanced training in taxon-specific expertise ("Adapting to the Future: Report of the BBS Task Force Looking to the 21st Century", NSF 91-69).

In partnership with academic institutions, botanical gardens, freshwater and marine institutes, and natural history museums, the NSF seeks to enhance taxonomic research and help prepare future generations of experts. NSF has announced a Special Competition, Partnerships for Enhancing Expertise in Taxonomy (PEET), to support competitively reviewed research projects that target groups of poorly known organisms. Projects must encourage the training of new generations of taxonomists and translate current expertise into electronic databases and other formats with broad accessibility to the scientific community.

Projects designed for five years of effort are encouraged, with yearly budgets not to exceed $150,000 (direct plus indirect costs), or $750,000 total. Group Proposals could increase the budget according to the number of Principal Investigators involved. Standard components of taxonomic monography—species description and diagnosis, geographic distribution, scientific nomenclature, identification keys, illustration—are expected in all projects; training of two students and computerization activities are also required. NSF anticipates making 10-20 awards in the 1995 fiscal year in this special competition, contingent upon availability of funds and quality of proposals received.

Proposals should be submitted for a 1 March 1995 postmark deadline to the address given in the "Grant Proposal Guide" (NSF 94-2, page 2). NSF's "Grant Proposal Guide" provides relevant forms and rules for proposal preparation. On the cover sheet, upper left corner, write "DEB-PEET (NSF 94-109)" to expedite processing. Institutional cost-sharing in accordance with standard NSF rules is expected on all projects. Institutional commitment to the employment of taxonomists during and beyond the duration of PEET projects provides one clear example of partnership in answering the scientific and societal challenge of diminishing taxonomic expertise.

For the PEET Special Competition announcement, contact: Division of Environmental Biology (PEET), National Science Foundation, Suite 635, 4201 Wilson Boulevard, Arlington, VA 22230, 703-306-1481; fax: 703-306-0367; e-mail: sysrev@nsf.gov NSF 94-109 (new). [from *BIODICEN-L Distribution List*, August 1994]

Biosystematics provides the knowledge needed to conserve biodiversity, to sustainably use existing biological resources, and to develop new bio-industries. Those nations that develop that knowledge will have the power to manage their future. Those that fail to do so will be technical colonies of those that do. Investing in knowledge is investing in the future. [D.E.M.].

New Centre for Biodiversity Research opens at University of British Columbia

The newly established Centre for Biodiversity Research, University of British Columbia, Vancouver, Canada, will focus on the development of comprehensive and rigorous theories for evaluating and conserving the Earth's biological resources. It is an interdisciplinary

research unit in the Faculty of Science and brings together faculty with biodiversity research interests. Subsidiary objectives are centered around the development of new methods for biodiversity inventory and monitoring, and the development of new taxonomic data. The Centre will draw upon over 50 faculty members at the University with an interest in biodiversity research with strengths in the molecular/genetic group, the biological elements group, and two subgroups within the ecological resources group.

The closing date for applications for the position of Director of the Centre for Biodiversity Research was 1 October 1994. For further information contact: Dr. G.G.E. Scudder, Interim Director, Centre for Biodiversity Research, Faculty of Science, The University of British Columbia, 6270 University Boulevard, Room #1505, Vancouver, B.C. V6T 1Z4, Canada, Fax: (604) 822-5558.

Support mounts for Clean Coral Reefs Campaign

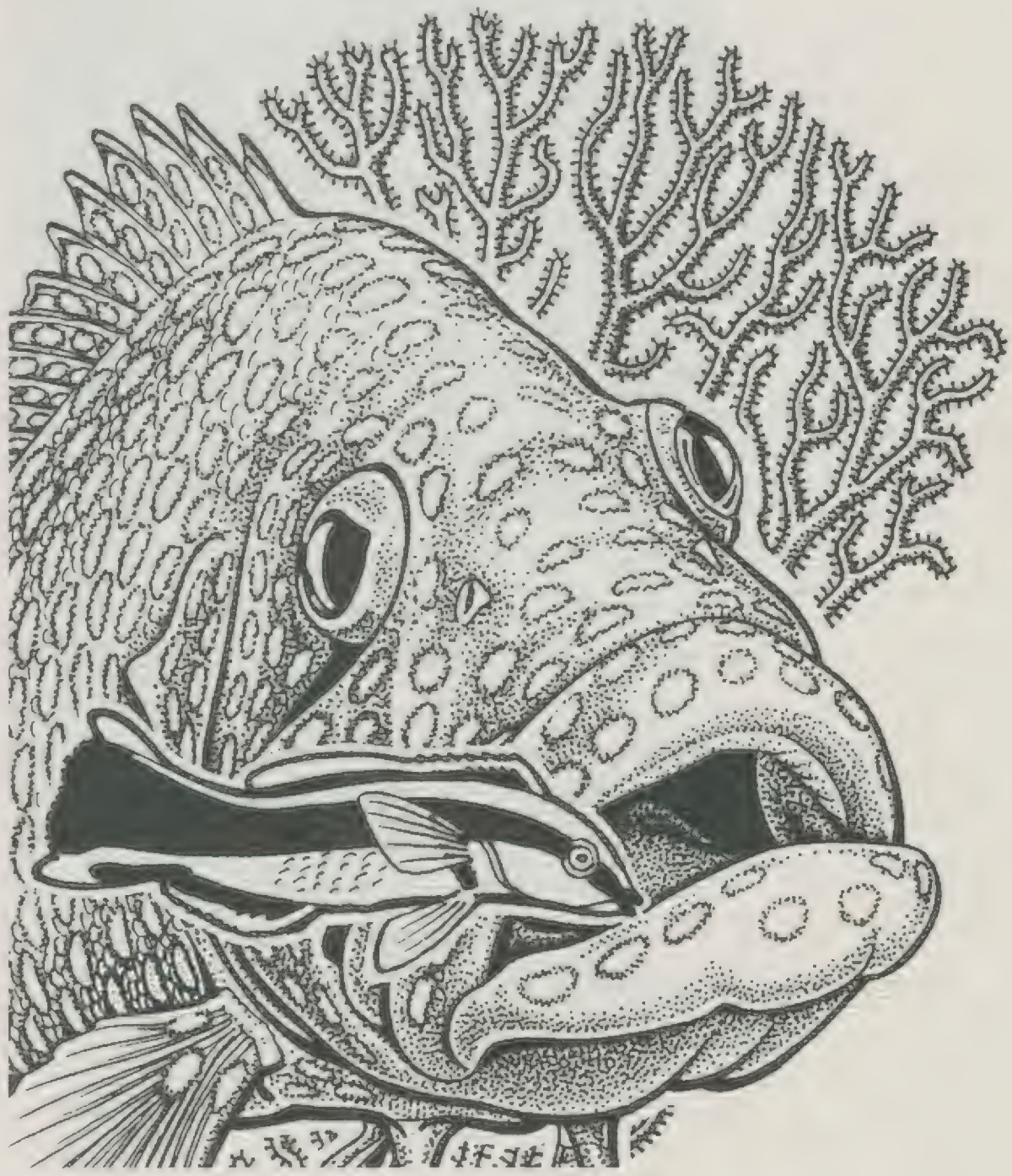
Since the national coral reef conservation organization Project ReefKeeper submitted a formal request in late 1993 to the Environmental Protection Agency (EPA) for the development of nutrient discharge standards for seagrass and coral habitats, 17 organizations representing over one million members and an additional 1,400 concerned individuals have lined up in support of the adoption of those nutrient standards.

Excessive nutrients are the most concerning pollution threat to coral reefs, which are adapted to nutrient-poor waters. Excess nutrients in coral reef areas can cause light-blocking phytoplankton blooms, stress-induced coral diseases, and coral-smothering algae over-growths. That's why the Clean Reef Campaign seeks adoption of nutrient water quality standards which do not exist for marine waters under any jurisdiction.

Divers, clubs, and dive stores are still being asked to participate in this nationwide grassroots Clean Reefs Campaign by Project ReefKeeper. "By providing petition forms and model group resolutions, Project ReefKeeper makes it easy for concerned divers to participate in this protection effort aimed at the federal EPA and state regulators," explained Project ReefKeeper Director Alexander Stone. "A strong grassroots response is that current federal and state water quality standards are not adequate for coral reef areas and that action is needed now," Stone continued.

Some of the groups already endorsing the Clean Reefs Campaign include the Environmental Association of St. Thomas (U.S. Virgin Islands), the Committee for the Conservation of Culebra's Marine Life (Puerto Rico), Hawaii's Thousand Friends, the Florida League of Anglers, and the Sierra Club National Marine Committee. "The outpouring of endorsements by these groups and many others covering coral reef areas throughout the United States makes it obvious that there is broad public support for protection by EPA of our very special coral habitats through the adoption of nutrient standards," declared Stone.

The Clean Reefs Campaign seeks to push regulators into that action through collection of petition signatures at dive store counters, and adoption of resolutions by dive clubs and other groups. "We will still need many more groups and individuals to sign on to the Clean Reefs Campaign before we can convince regulators that they must take strong action now and make adoption of nutrient water quality standards for coral reef areas a priority," concluded ReefKeeper spokesperson. [For free information about the Clean Reefs Campaign, contact Project ReefKeeper, 2809 Bird Avenue Suite 162, Miami, Florida, U.S.A. 33133, or fax: (305) 642-4996.



Cleaner fish keep reef fish healthy by removing their parasites and cleaning their wounds.

Genetically engineering juicier oysters

Scientists at Rutger University's New Jersey Agricultural Experimental Station Research Laboratory have developed a tetrapoloid variety of oyster–one with 40 chromosomes, double the normal complement. Normal oysters are diploid with 20 chromosomes. Crossing the new variety with the normal oyster produces triploids with 30 chromosomes.

The normal diploid lose much of their flavor during the spawning season. The artificial triploid does not reproduce and remains plump and juicy the year-round. That extends the marketing season for oysters. [Christopher S. Guy, 1994, Fisheries 19(7): 46-47.]

Oyster breeders may have an additional advantage: they can conduct the hybridization necessary to produce the triploid and sell them to oyster farmers who may lack that capacity. This could disempower some oyster farmers from raising their own spat or seed, and from developing varieties adapted to their local environmental conditions, just as the marketing of hybrid corn varieties prevents many farmers from growing their own equally productive seed corn. [D.E.M.]

British Columbia to Restore Garry Oak Habitat

The Lieutenant-Governor of British Columbia (B.C.), David Lam, has decided to restore 9 hectares of Garry Oak habitat. The Lieutenant-Governor's official estate on Rockland Avenue in Victoria, B.C., contains a significant piece of this habitat, increasingly threatened by development and introduced exotic species on southern Vancouver Island. The estate is infested by non-native plants such as Scotch broom and Himalayan blackberry. These exotic species will be removed so that camas, shooting star and other wildflowers native to the site can flourish. [*Beautiful British Columbia* 36(2): 47, 1994].

Canadian Prime Minister Announces Members of National Round Table

Prime Minister Jean Chrétien announced the proclamation of Bill C-72 officially creating the **National Round Table on the Environment and the Economy** (NTREE) and announced the formal appointment of the Round Table Membership.

The Round Table was established in 1988 as an independent, multi-sectoral body which plays the role of catalyst in identifying, explaining and promoting, in all sectors of Canadian society and in all regions of Canada, principles and practices of sustainable development.

The Round Table brings together eminent Canadians from all sectors of society, government, industry, labor, academia, and environmental organizations dedicated to the promotion of sustainable development in Canada.

The membership is as follows:

- Dr. George Connell, Chairperson
- R.C.(Reg) Basken, Executive Vice-President, communications, Energy and Paperworkers Union
- Diane Griffin, Executive Director, Island Nature Trust
- R.A. (Tony) Hodge, Consultant
- Dr. Pierre Marc Johnson, Research Director, McGill Centre for Medicine, Ethics and Law
- Dr. Geraldine A. Kenney-Wallace, President and Vice-Chancellor, McMaster University
- Jack M. Macleod, Corporate Director
- Dr. Robert Page, Dean, Faculty of Environmental Design, The University of Calgary
- His Honor Judge Barry D. Stuart, Territorial Court of Yukon
- Elizabeth May, Executive Director, Sierra Club of Canada
- Patrick (Paddy) Carson, Vice-President, Environmental Affairs, Loblaw Companies Ltd.
- Dr. Harvey L. Mead, President, Union québécoise pour la conservation de la nature
- Dr. Stuart L. Smith, President, RockCliffe Research and Technology Inc.
- Dr. Arthur J. Hanson, President and CEO, International Institute for Sustainable Development
- Alan D. Bruce, Administrator, Local 115, Canadian Union of Operating Engineers
- Cindy Kenny-Gilday, Special Advisor, Department of Renewable Resources, Government of the N.W.T.
- Elizabeth Jane Crocker, Secretary-Treasurer, Plovers, Halifax

- The Honorable Lise Bacon, Former Minister of the Environment and Deputy Premier of Quebec
- Janine Ferretti, Executive Director, Pollution Probe Foundation
- Karen A. Morgan, Community Activist, Delta, B.C.
- Loreen May Williams, Lawyer, Harper Grey Easton
- The Honorable Maurice F. Strong, Chair, Ontario Hydro
- G. Martin Eakins, Partner, KPMG, Peat, Marwick, Thorne
- Sam Hamad, Vice-President, Groupe-Conseil Roche Ltée

The Round Table formally reports to the Prime Minister and, as such, is in a key position to influence and add value to ongoing efforts to meet the goal of sustainable development.

Canadian Museum of Nature specialists win Outstanding Achievement Award

Natural history museums have been key players but little recognized for their vital roles in providing information on biodiversity. This was recently recognized in an Award for Outstanding Achievement given to two staff members of the Canadian Museum of Nature (CMN) by the Canadian Museum Association at their annual convention in Newfoundland, July 17.

The two Museum specialists, Dr. Don E. McAllister and Robert McFetridge, have helped Canada fulfill its obligation to the International Convention on Biological Diversity, the global effort to preserve all living organisms and their habitats.

McAllister's and McFetridge's efforts and scientific expertise have contributed to Canada's international leadership in developing the Convention, and museums of natural science such as the CMN have been recognized as major players in the development and implementation of biodiversity strategies. McAllister and McFetridge pointed out that the Canadian Centre for Biodiversity acts as a doorway to the research, collection, and biological inventory expertise and knowledge of the museum, and that the award was accepted in the names of their many colleagues who have established this biosystematic and biodiversity knowledge base.

Don McAllister, the Museum's Senior Biodiversity Advisor and leader of the Canadian Centre for Biodiversity, and Robert McFetridge, Programme Director for Environmental Issues, have recently worked with the United Nations Environmental Programme in developing international guidelines for country studies on biodiversity, helped develop biodiversity country studies for Canada and Costa Rica, contributed to the *Canadian Biodiversity Strategy*, produce the internationally recognized bulletin, *Global biodiversity*, and provide scientific expertise to the Biodiversity Convention Office of Environment Canada.

Michael V. Cheff (left), President of the Canadian Museum Association (CMA) and CMA Award recipient Robert McFetridge, Programme Director for Environmental Issues, Canadian Museum of Nature. Don McAllister not present for photo.

Cyberdiversity: Biodiversity and the Internet

GETTING STARTED

I confess that it took me five years to use my bank card, I still don't have a calling card, and I can barely set the time on my VCR. However, for the last few months I've been navigating the Internet, or cyberworld. Today, for example, I received and responded to e-mail from Japan and Colombia, contributed to a discussion about a U.S. National Biodiversity Info Center, and received notice that my daughter-in-law is coming to visit us. E-mail through Carleton University's National Capital Freenet provides me with many new contacts and new ideas for my work in the Canadian Museum of Nature and Ocean Voice International (an environmental NGO). It saves money in communication costs, faxes, and phone calls that might otherwise have to be made, and provides speedier service than regular mail, or snail mail as it is called in cyberworld. I must learn to up- and down-load files (it's relatively simple) and how to use gophers to sniff out information for me. But even with my simple level of knowledge, I get a lot from the Internet and have fun doing it. The moral of the story is that even a person who is technology-shy can easily use the Internet.

Internet is a global, non-commercial, electronic network with more than 20 million computers communicating through it. It consists of university, government, and industry computers, which serve as nodes to which your personal computer (or local building computer network) can link up. The nodes are linked by communication lines to one another.

You can link up with Internet, move into cyberspace, and join the budding information highway. This is what you need: a personal computer, a modem (an electronic box which enables your computer to talk with other computers over the phone line), a communications program for your computer, and a phone line.

With those things in hand you establish an account with a nearby node (nearby means no or only short long-distance phone calls to the node). In some fortunate cities there is a Freenet, a local community service node that charges no fee. If you are associated with a university, a government agency, or a company, you may be able to have free access to their node. Or you can pay a fee to a commercial firm that offers connections to Internet as well as other services. Large commercial firms include CompuServe, America Online, Prodigy, and Delphi, but there are many smaller, local ones called bulletin board services (BBS). There are up to 100,000 BBS in North America, many devoted to specialty areas.

With an account you will be provided with a login number and a password, and storage space that acts as your mailbox. To send an e-mail letter you need to know the person's e-mail address and you will choose the "send a letter" option in the post office menu of your local node. Then you will type in the letter, sign off, and "send" the letter. The letter could go to a "postbox" for someone in the same building or on the other side of the world—for no fee in many cases, and much faster than regular snail mail.

E-mail is only one of the features of Internet. Discussion groups, lists, databases, downloading information and images, searching libraries, and checking airline flight schedules are just a few of the items that can be accessed using the Internet.

In future issues of *Global biodiversity*, this column will review some of the lists, usergroups, information services, etc. that provide information or contacts with biodiversity people. If you have information on biodiversity-related topics available on the Internet, please contact: Noel Alfonso, Technical Editor, at the address on the inside front cover, or by e-mail at ah201@freenet.carleton.ca

For more complete information on what's out there in cyberworld and how to link up with Internet, check out some of the following references [D.E.M.].

Suggested Reading

- Barlow, John Perry. 1994. Netguide. Your map to the services, information, and entertainment on the electronic highway. Random House, New York. 356 pp. Paperback, ISBN 0-679-75106-8. US$19.00. The first 28 pages provide

easy to understand information on what Internet is and how to link up with and use Internet facilities. The rest of the book is a guide to what you can find on Internet. Part 11 is on Nature, Science and Technology. There is a page on Biology and two on Environment with useful things like bionet, Darwin-L (L=list), Ecology Network, Environet (Greenpeace BBS), and much more. An index helps find what you want.

■ Braun, Eric. 1994. The Internet directory. Fawcett Columbine, New York. 704 pp. Paperback, ISBN 0-449-90878-4. Can$32.50, US$25.00. This book provides you with more than 1,500 Internet and Bitnet mailing lists, 2,700 Usenet newsgroups, 1,000 on-line library catalogs, 100 anonymous FTP archives and archie servers, 300 gopher servers, 250 electronic journals, and more. There is an index.

■ Dern, Daniel P. 1994. The Internet: Guide for new users. McGraw-Hill, Inc., New York. 570 pp. Paperback, ISBN 0-07-016511-4. Can$39.95, US$27.95. Part 1 deals with getting started, Part 2 with electronic mail, usenet, remote log-in, and file transfer, Part 3 with navigating the Internet, Part 4 with help problems, security and being an Internet citizen, Part 5 with commercial services, archives, communities, etc. It has an index and a glossary.

WCMC Conservation Service on Internet

In mid-September, the World Conservation Monitoring Centre (WCMC), will launch new conservation services on the Internet, including a *home-page* running under *Mosaic* software to provide flexible access to a wide variety of information on species, protected areas, habitats, and wildlife trade. To contact these services address e-mail to:

duncan.bennett@wcmc.org.uk

If you do not have access to either the Internet or e-mail, but have firm expectations of gaining access, a fax containing any details you can provide would be welcome.

Duncan Bennett, WCMC, 219 Huntingdon Road, Cambridge CB3 0DL, U.K., Fax: 44-223-277-136.

Biodiversity Meetings

29 DECEMBER 1994-5 JANUARY 1995

Second World Congress on Herpetology, to be held in Adelaide, Australia.

Contact:
Michael J. Tyler
The University of Adelaide
Department of Zoology
Box 498 GPO
Adelaide 5001, South Australia

3-6 JANUARY 1995

Meeting of Population Genetics Groups, to be held in Exeter, U.K.

Contact:
Dr. M.R. MacNair
Hatherly Laboratories
Department of Biological Sciences
University of Exeter, Prince of Wales Rd.
Exeter EX4 4PS, U.K.
Fax: 44-0392-263700
e-mail: popgroup@exeter.ac.uk

5-7 JANUARY 1995

Society of Canadian Limnologists: 1995 Annual Meeting, held concurrently with the **Canadian Conference for Fisheries Research** (CCFFR), to be held in Ottawa, Ontario, Canada.

Contact:
Patricia Chambers
National Hydrology Research Institute
11 Innovationa Blvd.
Saskatoon, SK
S7N 3H5
Tel: (306) 975-5592
Fax: (306) 975-5134

19-23 FEBRUARY 1995

Seventh European Congress on Biotechnology, to be held in Nice, France.

Contact:
Société de Chimie Industrielle
28 rue St. Dominique
75007 Paris, France
Tel: 33-1-45-55-69-46
Fax: 33-1-45-55-40-33

9-12 MARCH 1995

Wolves and Humans 2000: A Global Perspective for managing conflict, to be held in Duluth, Minnesota, U.S.A.

Contact:
Marge Erikson, Registrar
Continuing Education & Extension
University of Minnesota Duluth
316 Darland Administration Building
10 University Dr.
Duluth, MN 55812-2496 U.S.A.
Tel: (218) 726-6819
Fax: (218) 726-6336
e-mail: merikso@d.umn.edu

27-30 MARCH 1995

Special Symposium - The Ecology of Arctic Environments, to be held in Aberdeen, U.K.

Contact:
The British Ecological Society
26 Blades Court
Deodar Rd.
Putney, London, U.K.

22-26 APRIL 1995

Tenth Annual Landscape Ecology Symposium - Working in a World Dominated by Humans: Theory and Practice of Landscape Ecology, to be held in Minneapolis, Minnesota, U.S.A.

Contact:
Nancy E. Grubb
Professional Development and Conference Services
University of Minnesota
222 Nolte Centre
315 Pillsbury Drive SE
Minneapolis, MN 55455-0139 U.S.A.

22-28 MAY 1995

Bioindicators: 8th International Symposium on Biological Indication of the State of the Environment, to be held in Ceské Budejovice, Czech Republic.

Contact:
Jaroslav Bohac
Institute of Landscape Ecology
Academy of Sciences of the Czech Republic
Na sadlach 7, Ceské Budejovice
Czech Republic
Fax: 4238 457 19

23-25 MAY 1995

International Smithsonian / MAB Symposium.
Measuring and Monitoring Forest Biological Diversity: The International Network of Biodiversity Plots to be held in Washington, D.C., U.S.A.

Contact:
Dr. Francisco Dallmeier
Chair, Symposium Planning Group
1100 Jefferson Drive, S.W., Suite 3132
Washington, D.C. U.S.A. 20560
Tel: (202) 357-4793
Fax: (202) 786-2557
e-mail: IC.FGD@IC.SI.EDU

5-9 JUNE 1995

Sustainable Forests Conference: Integrating the Experience. An International Conference on Implementing Ecosystem Management, to be held in the twin cities of Sault Ste. Marie, Ontario, Canada, and Sault Ste. Marie, Michigan, U.S.A. This hands-on conference is designed to take you from academic philosophies to development of an actual ecosystem management plan.

Contact:
Joan Jaffit
c/o BRIDGE
Sault College of Applied Arts & Technology
P.O. Box 443, Northern Ave.
Sault Ste. Marie, ON P6A 5L3
Canada
Tel: (705) 759-2554 ext. 747
Fax: (705) 256-6165

15-19 JUNE 1995

American Society of Ichthyologists and Herpetologists, American Elasmobranch Society, and **Herpetologists League** to be held on the campus of the University of Alberta, Edmonton, Alberta. Several symposia are planned along with contributed papers.

Contact:
Joseph S. Nelson or Mark V.H. Wilson
Department of Biological Sciences
University of Alberta
Edmonton, Alberta T6G 2E9, Canada
Fax: (403) 492-9234.

Book and Periodical Niche

Fishes of Taiwan

Chief editor Shih-Chieh Shen. 1994. Institute of Zoology, National Taiwan University, Taipei, Taiwan, R.O.C. 960 pp., 29 x 21 cm. ISBN 957-9019-44-4.

This very impressive volume describes the 2,028 species known from the ocean and freshwaters of Taiwan. Six other ichthyologists collaborated with Professor Shih-Chieh Shen to write the various sections. The basic text is in Chinese. The scientific names (with author) and synonyms are in English, and have been proofed by Dr. W.N. Eschmeyer. Keys, diagnostic characters, distributional notes (these three are in Chinese), and major references are given for the families, genera and species. The introductory section includes 11 pages of line drawings, primarily to show various characters or body parts. There are 208 colored plates, most with 10 species per plate (plus 4 appended plates), an extensive bibliography, and a separate index for Chinese and English names.

Not all authors would recognize all of the nominal species as valid. Nevertheless, this valuable publication gives us an updated knowledge of fishes in this very species-rich part of the world.

Joseph S. Nelson, Department of Biological Sciences, University of Alberta, Edmonton, Alberta T6E 2E9, Canada.

L'ENVIRONNEMENT Magazine

38, rue Croix-des-Petits-Champs, 75001 Paris, France. Telephone: (1) 42 60 01 93. Fax: (1) 42 60 10 41. One year subscription (10 issues), 690 F; 70 F per issue. For foreign subscriptions, contact the Subscription Service at (1) 42 96 25 78.

This French magazine (10 issues per year) is now in its 148th year. Formerly known as the *Annales de la voirie et de l'environnement*, it is intended primarily for engineers, elected officials, eco-industries, industrialists, architects, urban planners, and nature protection associations. The focus of this publication is waste, pollution management, refuse collection, urban planning, energy, and nature.

Environmentally conscious, this publication is printed entirely on recycled paper. Columns (waste flash), special reports (green packaging in January 1993), a symposia and seminar timetable as well as articles with an international and European character can be found within its color cover, also printed on "green" paper! Above all, this periodical is a forum for companies working in the three R field: recycle, reclaim, and reuse. It is an interesting publication for those who want to find out what is going on in the pollution management field in Europe.

Jean Lauriault, Public Programming, Canadian Museum of Nature

Cordillera

A Journal of British Columbia Natural History published by the Federation of British Columbia Naturalists in cooperation with the Royal British Columbia Museum, Federation of British Columbia Naturalists, 321 - 1367 West Broadway, Vancouver, B.C. V6H 4A9, Canada. Annual subscription rate for individuals and organizations $20.00, for individual and organizational members of the Federation $15.00. Telephone: (604) 737-3057, Fax: (604) 738-7175. Address manuscripts and correspondence to Editor, *Cordillera*, Box 625, Kamloops, B.C. V2C 5L7, Canada.

On a visit to British Columbia I saw in the very first issue of this new magazine, dated March 1994, a view of British Columbia through the eyes of naturalists, both professionals and amateurs. An impressive aerial-photo coloured cover graced 48 pages of text with black and white photos.

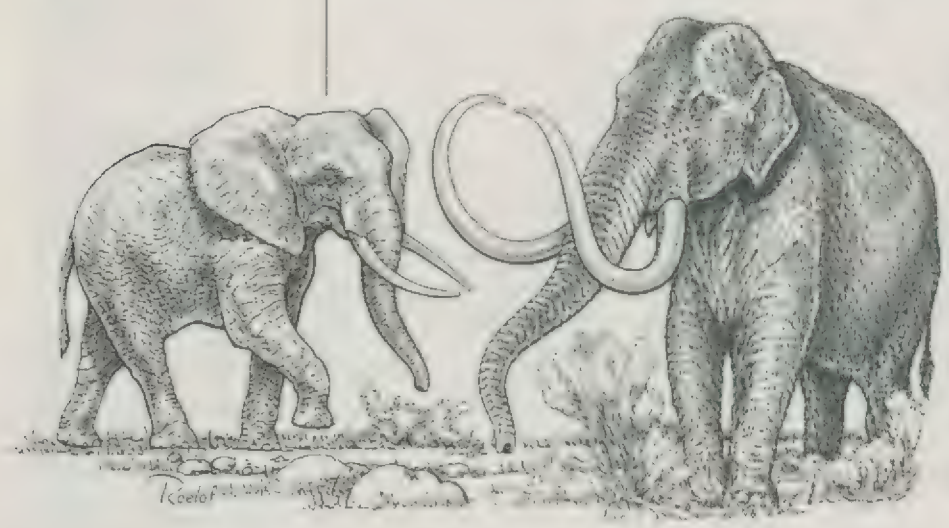
The contents are divided into the following sections: Features, Discovery, Notebook, and Departments. The first feature article describes the fameflower, *Talinum sediforme*, a small rockplant endemic to south central B.C. and neighbouring Washington state. A full and fascinating account is given of this species, known only from 13 localities in Canada and 6 in the United States, and generally restricted to outcroppings of a volcanic sheet.

In the Discovery section an entomologist and naturalist reports encounters with the red and the yellow underwing moth, *Catocala* sp. These species, which are becoming rare at some localities, can be attracted to night baits of molasses, stale beer, and rum spread on tree trunks. The underwing is named for the striking colours shown on the lower wing. In the notebook section Yorke Edwards and Robert Greig report on the discovery of hawk migration paths on Vancouver Island; a second notebook article looks at fishing screech owls. The Department section includes book reviews, news on research at the Royal British Columbia Museum, and a survey of forest research.

Cordillera is a well-written magazine that presents intriguing research by scientists and observations by naturalists. It makes for enjoyable and informative reading. [D.E.M.]

Mammoths, mastodonts, and elephants: biology, behavior, and the fossil record.

By Gary Haynes. 1991. Cambridge University Press, Cambridge, UK, 413 pp., US$69.50 (cloth), ISBN 0-521-38435-4.



Elephants spring to mind in various ways: Walt Disney's colourful tale of Dumbo, the flying elephant (surely Dumbo must have been based on a young African elephant with those long ears!); the exciting 1977 find of a well-preserved carcass of a baby woolly mammoth named Dima that had died some 40,000 years ago in northeastern Siberia; and the flaming mountain of African elephant tusks in Kenya—a beacon of hope for conservationists—signifying a closing down of trade in ivory there.

This book delves well below these surface images. Haynes, an archaeologist by training, applies James Hutton's principle of 1785 "the present is the key to the past," using his knowledge of modern African elephant bone accumulations in Zimbabwe's Hwange National Park as a way of interpreting mammoth and mastodon fossil sites. Are there parallels between the extinction of mastodons and mammoths about 10,000 years (or less) ago and the decline of modern elephants? The relatively new (defined by Efremov in 1940) discipline of taphonomy—the study of processes occurring between the death of an animal and its recovery as a fossil—is central to this issue.

The book consists of three parts, The first, "Proboscidean [elephants and extinct related forms such as mammoths and mastodons] flesh and bones," stresses the similarities between living conditions of past and present proboscideans, and deals with their classification and physical appearance as well as presenting a model for understanding social structure and habitat use by mammoths and mastodons.

The second part, "Actualistic studies of proboscidean mortality," discusses studies of mass deaths and kills. Haynes notes that the main differences between natural death and kill sites are: (1) the presence of weapons and butchering damage on bones at kill sites, whereas such features usually are lacking at die-off sites; (2) the upland locations of kill sites and their covering by wind-blown sediment, in contrast to the stream-channel depressions or spring-fed ponds of die-off locations; and (3) the sparse representation of adult males at kill sites.

In Part III, Haynes uses data from earlier chapters to "find meaning in the fossil record." He discusses proboscidean sites throughout the world, simultaneously criticizing the work of others, and reviews mammoth and mastodon extinction near the close of the Pleistocene, concluding that they died off rather than were killed. The author's motives in writing the book "are to stimulate rethinking about mammoths, mastodonts, and elephants in

Quaternary [the last 2 million years] prehistory." He achieves this goal. Sadly, Haynes notes that the chances for continuing studies like those at Hwange are shrinking rapidly "because human beings may soon [perhaps within 20 years] kill off all the wild elephant populations left on earth."

Part III is followed by a handy Appendix on methods of determining age in proboscideans by studying degrees of tooth eruption and wear—and less frequently used techniques, such as limb-bone lengths and the degree to which the articular ends of bones (epiphyses) are fused to the shafts.

The book is interesting, clearly written, and based on extensive personal observations, as well as a survey of the pertinent literature (approximately 600 references are listed). It demonstrates the advantage of carrying out field studies on modern elephants when interpreting mammoth and mastodon bone deposits: the present can indeed be a useful key to the past.

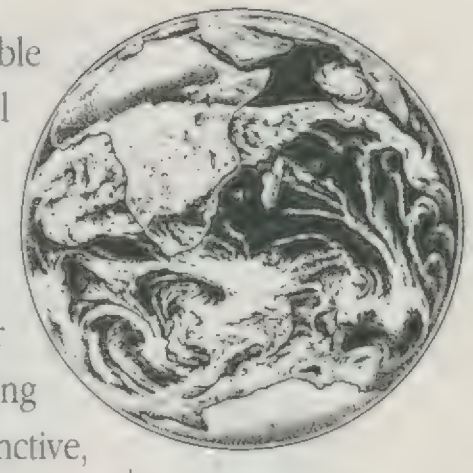
C.R. Harington, Research Scientist, Paleobiology, Canadian Museum of Nature

Caring for Creation: An ecumenical approach to the environmental crisis.

By M. Oelschlaeger. 1994. Yale University Press, New Haven. x + 285 pp. ISBN 0-300-05817-9. US$30.00

What a pleasure it is to recommend this excellent, thought-provoking, and truly interdisciplinary book to those who are deeply concerned about human effects on the biosphere. It is a work that does not preach, but teaches; that does not polarize, but unifies.

The author's geographic scope is restricted to the U.S., and attention is primarily (but not exclusively) focused on the Judeo-Christian churches that represent the religious affiliation of 85% of its citizens. His thesis may be summarized as follows: America's social and natural ecology is worsening because of the poverty of a public philosophy of "utilitarian individualism." Universities, corporations, and governments have lost touch with the vital interests of the average person, and only the churches remain as the single institution "...where habits of heart, the language of the community..." persist. The churches contain a cross-ecclesiastical consensus that humans are responsible for being good stewards of nature, and that nature has an intrinsic value of its own. Because they are primarily concerned with the welfare of the group, the churches are the strongest force able to resist a danger that the environmental crisis will lead to an "administrative despotism." Finding "environmentalists and religious believers... are coming together in a new era of green politics," he concludes that "...a new metaphor—caring for creation—can engender a psychologically satisfying (emotionally evocative, powerful), religiously distinctive, and scientifically plausible ethic for our time."



It would be a disservice to the author not to offer a few minor criticisms, which this reviewer is convinced he would welcome. Previously, a belief in the providence of nature under God was more widely held. However, humans were derived from nature under God, and are worthy of confidence as also ultimately being instruments of His providence (cf. p. 100). Indeed, in the future humans may protect the biosphere from periodic catastrophes caused by the impacts of asteroids and comets. The biosphere has changed throughout the history of the Earth. Humans would not be able to prevent change because we cannot suppress its causes, short of extermination. The biosphere will adapt (is adapting) to our presence, for better or for worse. Finally, the biosphere of our planet cannot exist eternally on Earth, for our planet will not always possess a surface environment hospitable to life. Only sentient creatures, like ourselves, could ultimately propagate it in suitable environments beyond the Earth.

There is much wisdom in this thoroughly non-offensive book, and its author is a friend to us all.

Dale A. Russell, Research Scientist, Paleobiology, Canadian Museum of Nature

Kadimakara: Extinct vertebrates of Australia

By P.V. Rich and G.F. van Tets, editors. 1990. Princeton University Press, Princeton, New Jersey. second edition. 284 pp. US$49.50 hardcover. ISBN 0-691-08733-4.

The legends of the Aborigines tell us that the animals of Dreamtime, the "Kadimakara" in the Dieri language, were wondrous, mystical beasts. To the Dieri, the fossil bones found today in the desert country of central Australia are relics of a time when the area was a fertile, well-watered plain, an Eden. The *kadimakara*, doomed to extinction when the balance of nature was destroyed, remain only as bones scattered on the dusty, parched salt pans of the interior.

One of Australia's present day vertebrates.

To most of us in the western and northern hemispheres, the origins of the unique, modern Australian fauna are equally mysterious. This coffee-table book, a beautifully illustrated update of the original 1984 edition, is a volume that easily forms the links between the fossil evidence of the animals of Dreamtime and today's characteristic vertebrates of Down Under. The book is a guided tour of exploration and discovery, a descriptive portrait of an ancient world, and a catalogue of highlights in the half-billion-year evolutionary history of a continent. The editors have mined the gems from fossil collections in Australian museums, and use the discoverer, researcher, or curator (often all the same individual) to describe each featured animal or group and interpret for us its significance. The numerous line drawings, photographs, maps, and Frank Knight's 31 full-page colour reconstructions of fossil fish, reptiles, birds, and mammals in their appropriate environmental contexts transcend the sometimes dry prose to render these obscure creatures believable, and more importantly, understandable, for the nonspecialist. An address list of Australian paleontological institutions, paleontologists and their specialties, and a selected, 400-item bibliography and an index make *Kadimakara* a useful reference.

The authors of the individual chapters are identified only in the table of contents, but they are collectively a *Who's Who* of modern workers in Australian vertebrate paleontology. Suffice it to say, they are eminently qualified. Two chapters deal with the history of paleontological investigations in Australia, and one gives excellent perspective by describing changing Australian environments throughout geological time. The short chapters on the *kadimakara* reflect the strengths of paleontological work as well as Australia's geological record: the concentrations are on the Devonian (408-362 million years ago), the Cretaceous (145-65 mya), the Miocene (23-5 mya) and the Pleistocene (last 1.6 my). Each discusses a particular animal or a related group, usually recounting the circumstances of discovery, some details of anatomical structure, a discussion of relationships with fossil or living relatives in Australia or elsewhere, and presumed mode of life and habitat.

There are four chapters on fossil fishes, including one on the superbly preserved Late Devonian assemblage at Gogo in the Kimberley region of northwestern Australia. Labyrinthodonts, the subject of one chapter, apparently left their tracks in Early Devonian sediments of western Victoria, probably the oldest record of tetrapods, the first land dwellers, anywhere in the world (Warren, *et al.* 1986). Intriguingly, although also mentioned only in the preface to this edition, Australia also provides the last record of this fossil group, fifty million years after the crocodile-like labyrinthodonts became extinct elsewhere (Rich & Rich 1989). Two fossil turtles are highlighted, including the remarkable horned *Meiolania* of Lord Howe Island, and there is one chapter on a pterosaur, a flying reptile. Three chapters feature marine reptiles, including an ichthyosaur and two plesiosaurs; one treats a varanid "lizard" much larger than the Komodo Dragon of Indonesia, and there are also chapters on a giant python and a terrestrial crocodile. Two dinosaurs are featured, as is a mammal-like reptile, a dicynodont. There are six chapters on extinct birds, including a giant penguin, a flamingo, and a large, moa-sized flightless creature, probably still alive when the Aborigines first made their way to Australia. Ten short chapters on Australia's remarkable fossil mammals conclude the individual accounts.

It is unfortunate that relatively new Australian discoveries, such as the world's oldest enantiornithines, primitive birds previously known from only Argentina, Mexico, and Mongolia (Molnar 1986), Australia's oldest mammal, the Early Cretaceous platypus *Steropodon* (Archer *et al.* 1985), and new, endemic, diminutive polar dinosaurs (Rich & Rich 1989) could not have been given full treatment as part of this revised edition.

Kadimakara, taken together with Mary White's (1990) *The Flowering of Gondwana: the 400 Million Year Story of Australia's Plants*, gives an excellent overview to the paleobiodiversity and historical biogeography of a remote and fascinating continent. Research on the fossil biota of Australia is increasing at a rapid pace, and this work will serve to place new discoveries in context.

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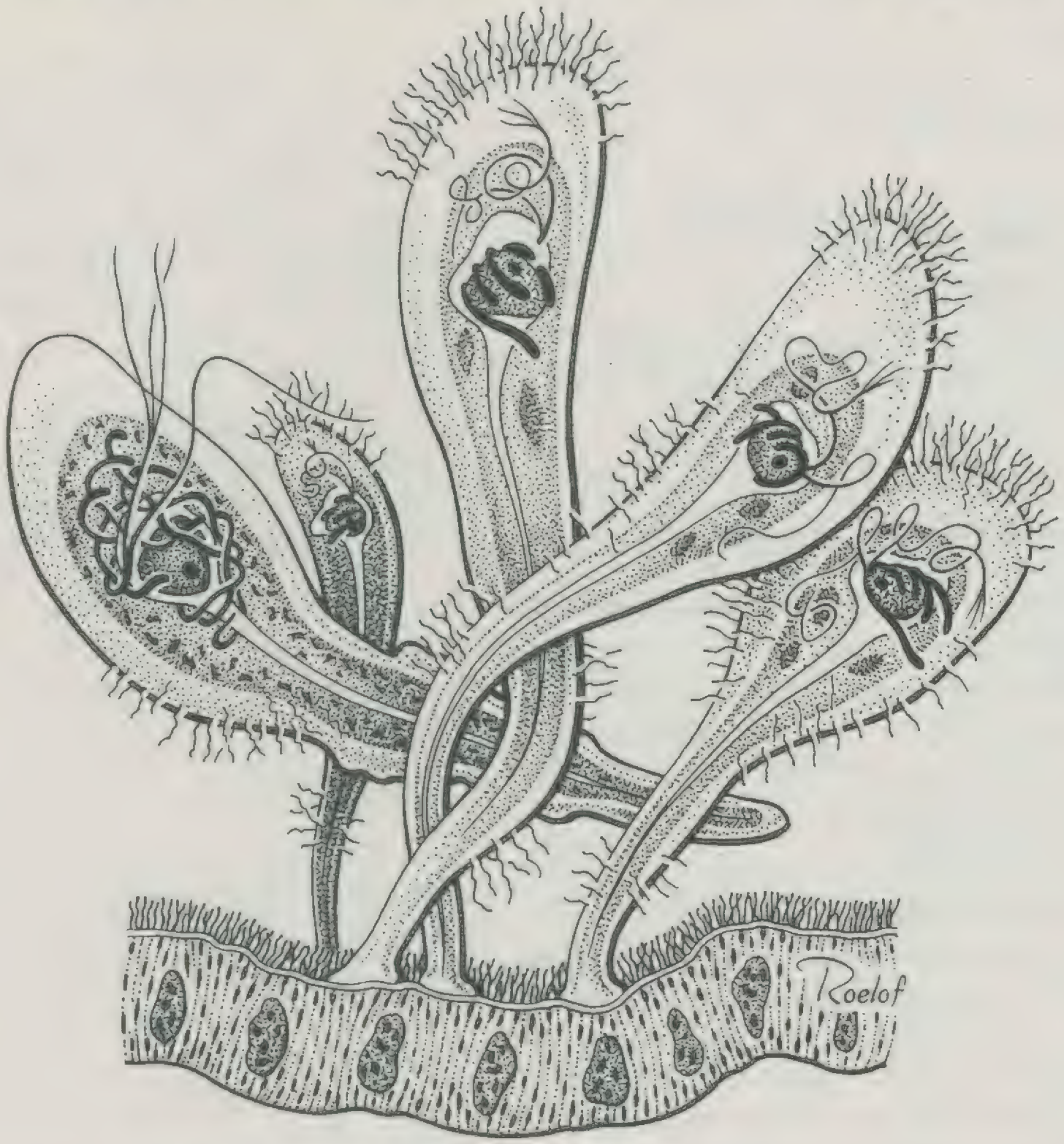


Kirbynia pulchra

This protozoan species is a symbiont (a participant in a sometimes mutually beneficial association) of a North African termite and is shown with attached hair-like spirochetes (bacteria). It is a facultative symbiont, meaning that it is able to live either within or outside of a termite hindgut. Some termite species need symbiont organisms to break down cellulose and lignin. The symbionts, widely differing bacterial and protozoan species, can make up as much as one third of the weight of an individual termite.

Termites are insects in the order Isoptera, separate from Hymenoptera (ants and wasps). Their closest living relatives are the cockroaches. Approximately one quarter of all termite species eat wood, with very significant impact on humans. All known species of termites are social. They live in colonies made up of individuals with rigidly defined roles: workers, soldiers, king, and queen.

There are four general guilds of termites: wood-dwelling, earth-dwelling, desert-dwelling, and carton-nest building (carton is a paper-like structural materal made by workers). The majority of termite species are earth-dwelling. They build large mounds (up to 5 m in height and 2 m in diameter), with walls made of cemented feces and sand. Cheetahs (*Acinonyx jubatus*) in savannah regions of Africa use termite mounds as lookouts for prey and predators, as structures to scent mark for territorial purposes, and for family play areas.

These relationships illustrate 3 of the 21 ecocological functions of biodiversity: symbiosis, communication, and nutrient cycling. Intricate relationships between unicellular organisms (spirochete bacteria and protozoans), arthropods (termites), and mammalian chordates illustrate just some of the many unexpected connections in the biosphere.

White, M.E. 1990. The flowering of Gondwana: The 400 million year story of Australia's plants. Princeton University Press, Princeton, NJ. 256 p.

Stephen L. Cumbaa, Research Scientist, Fossil Fishes, Canadian Museum of Nature

The reconstruction of fragmented ecosystems

By D.A. Saunders, R.J. Hobbs, and P.H. Ehrlich. 1993. Surrey Beatty and Sons, Chipping Norton, NSW, Australia, ISBN # 0 949324 50 7. £ 63.95

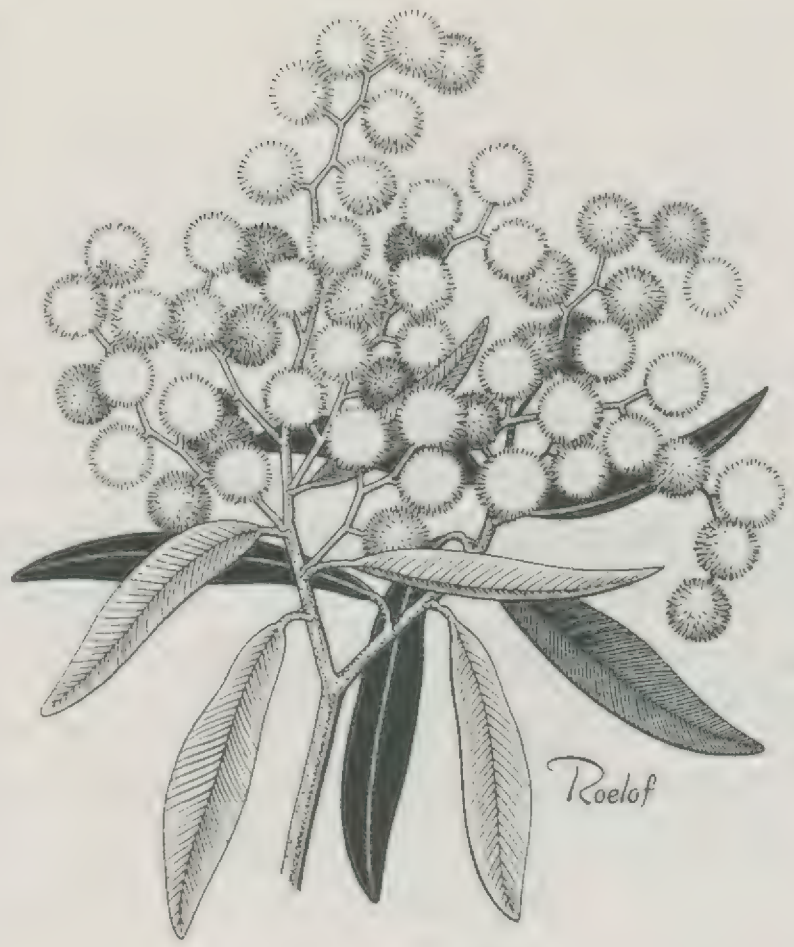
This is Volume 3 of the Surrey Beatty and Sons series *Nature Conservation* (the first two volumes dealt with the role of native vegetation remnants and the role of corridors, respectively. A fourth volume on the role of conservation networks is to be published early in 1995). As with the previous two collections, the current volume is the outcome of an international workshop held in 1991 and coordinated by the Commonwealth Scientific International Research Organization (CSIRO) Division of Wildlife and Ecology.

The material is presented in three sections. The first section, entitled *Global Perspectives*, is a general description of the issues involved in restoration ecology at a global scale, and how these large-scale problems impinge upon local and regional restoration projects. Most of the descriptive material contained therein is all too depressingly familiar to conservation biologists; of more interest (to this reader at least) are some of the suggestions about what we, as conservation biologists, should be doing to help resolve these problems. Paul Ehrlich suggests that we devote at least 10% of our time to promoting action on the large-scale problems that threaten the success of our more specialized, local efforts. Gretchen Daily and Anne Ehrlich make the important point, often not appreciated by research scientists, that our hopes for success of global restoration are pinned to a revolution in public thinking, and that (scientifically informed) environmental activism and public education might well be a more effective use of our skills than conservation research. Ted Lefroy and Richard Hobbs contribute a refreshing and witty description of the pychological succession of human responses to global problems, ranging from innocence and ignorance, through denial, acceptance, fear, technological optimism, hedonism and (finally) intervention. This description is important because identifying the appropriate mindset is a crucial first step in developing a public education strategy.

Section two, entitled *Regional and Local Perspectives*, is a heterogeneous collection of essays that revolve around the issue of whether certain general ecological principles (or "assumptions") are in fact valid at the regional and local scales. Yrjo Haila, Denis Saunders, and Richard Hobbs reiterate the point made years ago by Dan Janzen and (going even further back) Ed Wilson that uncritical application of the "traditional ecosystem approach" (whatever that is) is unlikely to be successful in the context of reconstruction of fragmented ecosystems on a local or regional scale; at this level, there is no substitute for knowing the specific ecological processes and organisms of importance to the particular situation.

The value (high or low) of corridors in restoration ecology is considered by several authors: Gray Merriam and Denis Saunders in the context of the impact of corridors on connectivity; Richard Hobbs and Harold Mooney in the context of invasion of exotic species; Harry Recher in the context of stemming the decline in Australian biodiversity; Dan Simberloff in the context of mitigating the impacts of fragmentation on Florida longleaf pine communities; and Marc Feldman in the context of local adaptation and stress response. The role of habitat edges, habitat patches, and native remnants in ecosystem restoration is addressed by Tom Sisk and Chris Margules, who consider methods from quantifying edge effects; Anne Scougall, Jonathan Majer and Richard Hobbs consider the impact of edge effects on grazed and ungrazed Western Australia wheatbelt; Robert Lambeck and Denis Saunders discuss the role of patches in providing habitat for native fauna; and Per Angelstram and Graham Arnold contrast the roles of remnants in old and recently impacted landscapes.

Section 3, entitled *Solutions: Making Restoration Ecology Work*, focuses on the practical aspects of restoration ecology. Here the emphasis is not on trying to understand the ecological processes at work in a particular fragmented ecosystem, but rather on what needs to be done in order to effectively implement scientifically plausible restoration schemes. John Cairns Jr., in the second-best essay in the volume, spells out very clearly what is needed to establish a favorable political and economic framework for ecosystem restoration, and the guiding principle for success in implementing restoration schemes. Juli Armstrong examines the question of whether the emphasis in



The Golden Wattle, *Acacia pycnantha*, is the unofficial national flower of Australia.

restoration projects should be placed more on the structural or the functional attributes of communities. The important issue of whether the restoration of natural communtities is compatible with agricultural land-use objectives is considered by Gary Fry and Barbara Main in the Austalian context, and by Bryn Green in the United Kingdom, while Ted Lefroy, Richard Hobbs, and M. Scheltema describe the nature and extent of revegetation required to restore basic ecological functions in the wheatbelt of western Australia. The role of community groups in restoration projects is examined using case studies of the Mission Beach District in north Queensland (F.H.J. Crome and J. Bentrupperbaumer) and the network of landcare groups in western Australia (K.F. Goss and Jos Chatfield).

The highlight of the volume is a personal essay by Don Couper, a farmer from Western Australia, on the history of land clearing and dryland salinization in the region. While we clearly disagree on several important issues (for example, the role—and validity—of "preservationist" environmental groups), he speaks from the heart in a language that all can understand. Particularly useful is his articulation of the criteria that must be met if farmers are to participate willingly in ecosystem restoration projects; practising conservation biologists would do well to pay attention.

The volume, while informative, suffers on several fronts. First, the title is perhaps a bit misleading: many articles deal with the issue of ecosystem restoration generally rather than the reconstruction of fragmented ecosystems specifically, and most of the case studies are (not suprisingly) from Australia. Second, many of the general points made in the first section have been made before, and the arguments developed in greater detail elsewhere. Third, with the exception of Paul Ehrlich's concluding essay, there is relatively little specific information about how to do what actually needs to be done to convince the public of the need for ecosystem restoration. Yet most would agree that this is undoubtedly our greatest challenge.

Scott Findlay, Department of Biology, University of Ottawa, 30 Marie Curie, Ottawa, Ontario K1N 6N5

Terrestrial ecosystems through time: evolutionary paleoecology of terrestrial plants and animals

Edited by A.K. Behrensmeyer, J. D. Damuth, W. A. DiMichele, R. Potts, H.-D. Sues, and S. L. Wing. 1992. The University of Chicago Press, Chicago and London, xx + 568 p. ISBN (paper) 0-226-04155-7. $29.95US.

Quite succinctly, this volume contains a superb summary of the known geological record of terrestrial organisms. It should be required reading (and re-reading) for every scholar interested in paleobiology and recent ecology. The result of a three-day conference held near Washington, D.C., in mid-1987, and the subsequent labours of 33 contributors and six editors, it is composed of two parts (basic principles and evolutionary history) and contains a feast of information and an excellent guide to relevant literature through 1990. The number of citations suggest that less information is available for Mesozoic-Early Cenozoic time than for Paleozoic and particularly Late Cenozoic time.

The authors were surely greatly challenged by the task of successfully presenting succinct and inclusive overviews. There are many fascinating generalizations: the anatomic idosyncracies of Paleozoic organisms were inherited for all subsequent geologic time; Paleozoic trees formed open canopies and died after reproducing; the diversification of scavengers progressively reduced the probability of carcasses remaining undisturbed; the Eocene invasion of diatoms into freshwater environments resulted in an improvement in the fossil record of freshwater organisms; the greatest evolutionary events include the diversification of land plants, replacement of detritivory by herbivory, and the rise of humans to dominance.

Opportunities for further synthesis abound. For example, it is noted that relatively little attention has heretofore been given to the evolution of ecological associations of terrestrial organisms, although these have been demonstrated to exist in marine organisms (the "evolutionary faunas" of Sepkoski). Implicit throughout the text are the generalizations that evolution is usually neither progressive nor strongly linked to change in the biological (not physical) environment. Yet the figures introducing chapters suggest progress in fitness through geologic time, and in the text it is suggested that, at least at intervals, it seemed as if interorganismal competition was driving the evolution of plants. Examples remain to be sought which would show how organisms changed in harmony with the gross changes in the planetary environment (such as Mesozoic aridity and late Cenozoic cooling), or if evolution proceeded differently on different continents how this was related to a dissimilar biological context.

The more this reviewer read the book, the more he liked it. Generalists will find it a concise, readable overview, and for specialists it will be a source of ideas that will illuminate new avenues for research. It is truly a "five-star" publication.

Dale A. Russell, Research Scientist, Paleobiology, Canadian Museum of Nature

Environment

By Peter H. Raven, Linda R. Berg, George B. Johnson. 1993. Saunders College Publishing, Philadelphia, PA. 670 pp. hardcover, ISBN 0-03-014329-2. US $53.75

This book is offered as an introductory text for undergraduates, both in science and nonscience. The wide range of subjects, the imaginative art and graphics work, the beautiful photography, and the skillful use of sidebars, certainly make it attractive for such a purpose. However, if the currency and accuracy of the treatment of renewable energy resources and technology is any indication of the overall validity of the textual material, then the material should be thoroughly reviewed, revised, and updated before introduction to any classroom.

The sections on renewable energy are very much out of date, contain technical inaccuracies, and exaggerate and misstate the environmental impacts of renewable resources development, suggesting an uninformed bias.

The following specific comments illustrate some of the shortcomings of this chapter:

- Current worldwide geothermal installed capacity for electricity is about 8,000 MW, or more electrical production than 8 large nuclear plants.

- "The world's largest cluster of wind turbines" is *not* located in Hawaii. There are about 12 MW installed at the site mentioned, while the Altamont Pass in California has over 700 MW of turbines installed and operating. The best winds are not off shore as stated. The midwest sites are clearly more attractive for windpower plants development.

- The statement that "hydropower provides approximately one-fourth of the world's electricity" is correct. According to the Energy Information Administration, hydropower provided 23.5% of worldwide generation capacity in 1990. The statement that the worldwide hydropower potential is less than 15% is not correct. As an example, Argentina gets about half its electricity from hydropower, but to date they have developed only about 7,000 MW out of 44,000 MW of potential sites. The same is true in many parts of the world.

- The tone of the hydropower chapter apparently reflects either an anti-hydropower bias or an inadequate understanding of the technology, its employment and its effects. The discussion focuses on large dams, ignoring the fact that in the United States, at least, large dams are a thing of the past. Most current hydropower development in the U.S. is upgrade or modernization of existing facilities, and what new development is underway is primarily run-of-river, with small diversion structures.

- While large dam development is more prevalent in some other countries, for example in Asia and South America, and they can have serious environmental and safety impacts, the discussion has a "doomsday" flavor. The much more common run-of-river type development can have adverse environmental effects, such as turbine mortality, water quality, and instream flow. But mitigation technology does exist, is used, and is being improved, and together with carefully planned operations, these effects can be minimized.

Despite the attractiveness of this book, the text should be thoroughly reviewed, chapter by chapter, before being used as a text for any students, especially undergraduates. Awareness and understanding of

renewables is weak, at best, among even the well-educated population. To start the college level student off with a badly outdated, terribly inaccurate treatment of the use of renewables would greatly exacerbate the awareness problem. If the discussion of ecosystems, fossil fuels, nuclear energy are no more current or accurate, then this text could be a serious detriment to the intelligent assessment of our energy/environmental impacts and, therefore, to the rational process that results in a voice of reason in an age when uninformed, emotional reaction yields wrong answers, even when problems and issues may have been correctly defined.

Roland R. Kessler, Director of the Office of Renewable Energy Conversion, Department of Energy, Washington, D.C., and assisted by technical staff. 1000 Independence Ave. S.W., Washington, D.C. 20585

Global Warming

by Stephen H. Schneider. 1990. Vintage Books, A Division of Random House, New York, xiv + 343 pp. $17.50, ISBN 0-679-73051-6.

With "global warming" and "greenhouse effect" being two of the most commonly used words to discuss the environment, Schneider's book is timely in describing exactly what global warming is and what its effects could be. The book is both readable and informative and provides a good introduction for those who do not want to digest detailed scientific reports. The author, Stephen Schneider, is well known in connection with environmental issues, having written numerous books and papers on climate change and the human impact on it.

This book initially catches the reader's attention with a fictitious account of a future summer where North Americans are suffering the effects of a very hot, dry summer. The reader is then told in readable scientific terms what the greenhouse effect actually is, and how it differs from other natural climate changes that have occurred over time. According to Schneider, since the beginning of the industrial era there has been a 25% increase in CO_2 in the atmosphere due to human activities. Other trace greenhouse gases have also increased, for example, methane, by 100%. Both the potential heat-trap effect of these increases and the amount of increased warming of the earth are difficult to predict with accuracy, as is the future impact on the earth and its resources. As Schneider describes, this imprecision leads to a range of predictions on the effects of "global warming" from both ends of the political and environmental spectrum, including the one held by the conservative Marshall Institute that the uncertainties of climatic prediction did not justify any U.S. governmental policy response to greenhouse gas build-up (other than research).

One of the most dramatic chapters is that giving examples of the impact around the world of global warming. Sea level increases, inland drought, deforestation, and beach erosion are only some of the potential environmental effects. Schneider goes on to lament that the public is not being presented with a balanced or necessarily informed coverage of environmental issues by the media, which often focus on emotion rather than science. Finally, the book outlines a variety of strategies and options through which we can cope with and ameliorate global warming now and in the future. This book makes a good environmentally based guide to the issues and potential effects of global warming.

Kathy Stewart, Research Scientist, Zooarchaeology, Canadian Museum of Nature

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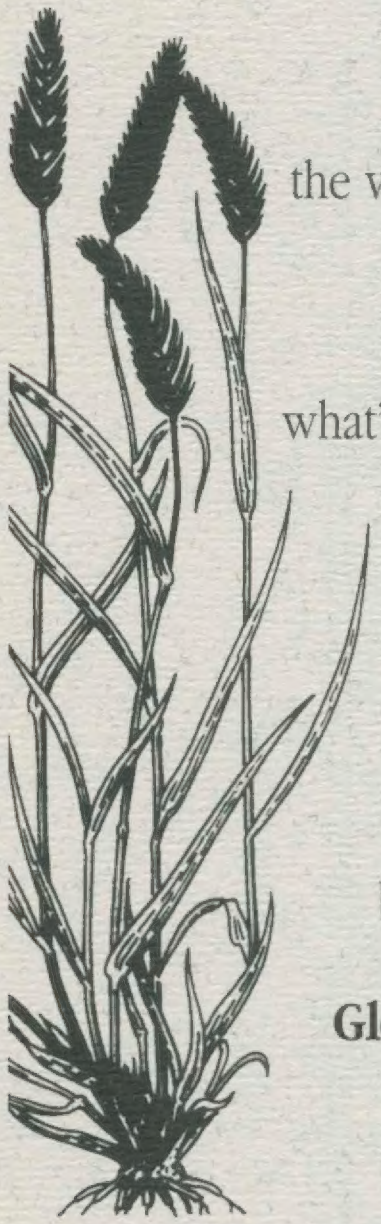

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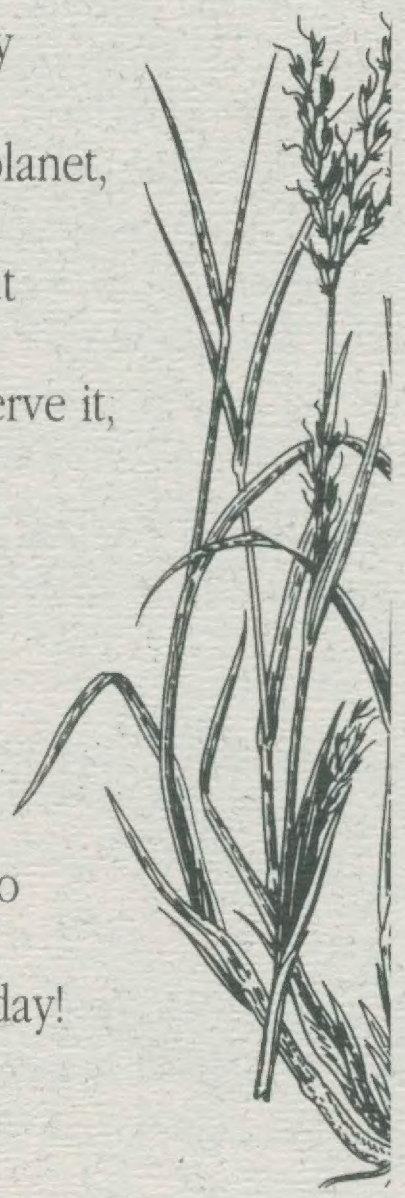

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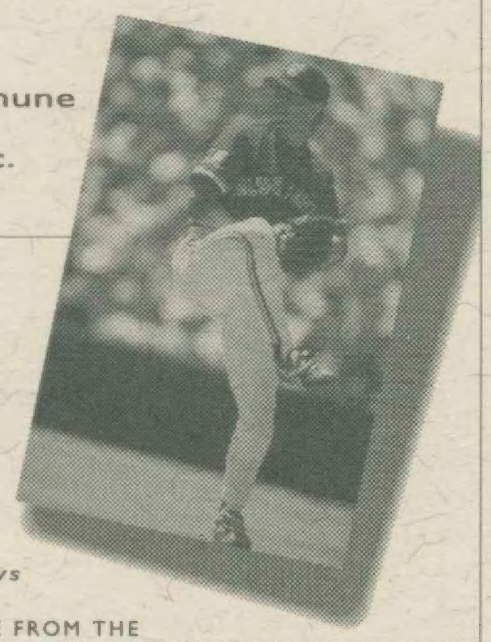

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Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4, Canada
ISSN 1195-3101 (English Edition) ISSN 1195-311X (édition française)

The great sea
Has sent me adrift,
It moves me as the weeds in a great river,
Earth and the great weather move me,
Have carried me away,
And move my inward parts with joy!

Inuit shaman woman poem
Quoted by K. Rasmussen, 1982, in ***News of the universe***, p. 257

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